COMPRESSED AIR

Established 1896.

A monthly magazine devoted to the useful applications of compressed air.

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COMPRESSED AIR CURVES AND TABLES.

WRITTEN FOR COMPRESSED AIR BY L. L. WILLARD.

The formulae for calculating the horsepower required to compress a given volume of free air to a given pressure are:

for single stage H. P. =

$$\frac{144\ P_1\ V_1\ n}{33000\ (n-1)}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}-1\right]\quad\ldots.(1)$$

for two stage H. P. =

$$\frac{144\times 2\ P_1\ V_1\ n}{33000\ (n-1)}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{2n}}-1\right]\quad(2).$$

for three stage H. P. =

$$\frac{144\times 3\ P_1\ V_1\ n}{33000\ (n-1)}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{3n}}-1\right]\quad\ldots.(3)$$

for four stage H. P. =

$$\frac{144\times 4\ P_1\ V_1\ n}{33000\ (n-1)}\left[\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{4n}}-1\right]\quad\ldots.(4)$$

where P_1 = atmospheric pressure taken as 14.7 lbs. per □".

P_2 = finial air pressure in lbs. per □" absolute.

V_1 = volume of air at P_1 pressure in cubic feet per minute.

n = exponent of the compression curve, taken as 1.4 which is for adiabatic compression. This will vary from 1.2 to 1.4 depending on efficiency of cylinder jacket cooling.

SINGLE STAGE

Gage Pressure	Absolute Pressure	No. of Atmospheres	H. P. per cubic ft. of Free Air	H. P. + 15% for Friction	M. E. P.	M. E. P. + 15%
5	19.7	1.34	.0197	.0227	4.50	5.17
10	24.7	1.68	.0362	.0416	8.30	9.55
15	29.7	2.02	.0504	.0580	11.51	13.25
20	34.7	2.36	.0628	.0722	14.40	16.55
25	39.7	2.70	.0742	.0853	17.00	19.55
30	44.7	3.04	.0845	.0972	19.40	22.30
35	49.7	3.38	0944	.1085	21.65	24 90
40	54.7	3.72	.1030	.1185	23.60	27.20
45	59.7	4.06	.1112	.1288	25.50	29.35
50	64.7	4.40	.1195	.1375	27.50	31.50
55	69.7	4.74	.1268	.1458	29.10	33.42
60	74.7	5.08	.1339	.1540	30.75	35.30
65	79.7	5.42	.1408	.1620	32.30	37.15
70	84.7	5.76	.1472	.169	33.80	38.90
75	89.7	6.10	.1532	.176	35.18	40.40
80	94.7	6.44	.1590	.183	36.55	42.00
85	99.7	6.78	.1650	.190	37.90	43.60
90	104.7	7.12	.1705	.196	39.10	44.92
95	109 7	7.46	.1758	.202	40.35	46.35
100	114.7	7.80	.1812	.208	41.65	47.85
105	119.7	8.14	.1841	.212	42.30	48.60
110	124.7	8.48	.1908	.219	43.75	50.35
115	129.7	8.82	.1965	.226	45.16	51.90
120	134.7	9.16	.2008	.231	46.00	52 88
125	139.7	9.50	.2045	.235	47.05	54.10
130	144.7	9.84	.2085	.240	47.80	55.15
135	149.7	10.18	.2135	.245	48.85	56.20
140	154.7	10.52	.2176	.249	49.90	57.35
145	159.7	10 86	.2220	.255	51.00	58.60
150	164.7	11.20	.2255	.259	51.70	59.50
155	169.7	11.54	.2300	.264	52.80	60.75
160	174.7	11 88	.2321	.267	53.40	61.45
165	179.7	12.22	.2361	.271	54 20	62.35
170	184.7	12.56	.2408	.277	55.25	63.50
175	189.7	12.90	.2465	.284	56.50	65.00
180	194.7	13.24	.2480	.286	57.00	65.65
185	199.7	13.58	.2516	.290	57.50	66.20
190	204.7	13.92	.2550	.293	58.25	67.00
195	209.7	14.26	.2565	.296	59.00	67.80
200	214.7	14.60	.2600	.299	59.75	68.75

—*L. L. Willard*

The cylinders should be so proportioned that equal work will be done in each.

For frequent use this formulae is inconvenient, requiring considerable time for its solution. For giving practically the same results the author has plotted the curves from values found by above formulae which will be found useful to any one calculating the power and size of air compressors. The tables are self-explanatory and the values are actual results. While the curves cannot be quite so accurate, they show very clearly the effects of compounding the cylinders and the saving in power and decreased temperature resulting thereby.

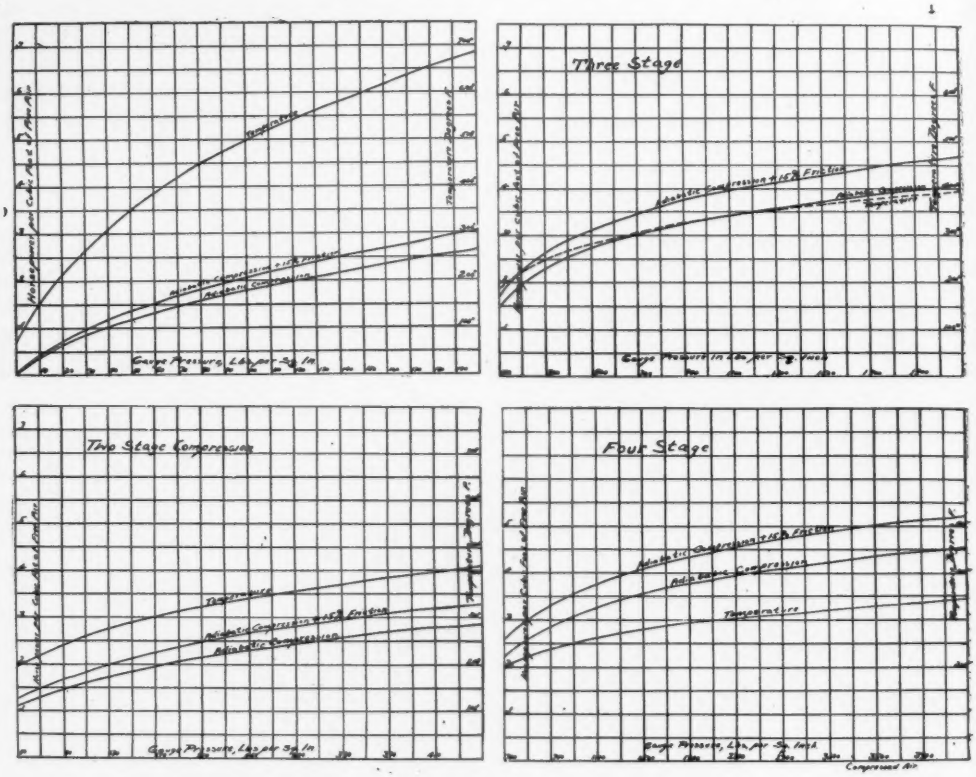
The values at the bottom of the diagrams represent the air pressure in pounds per square inch to which the air is to be compressed. The values at the extreme left are the horse-powers required to compress the air, both theoretically and with allowance for friction of 15 per cent.

If the compressor is to be located at a high altitude, less power will be required, and P_1 in the formula becomes less than 14.7, which will give a flatter curve. The horse-power varies directly as the weight of the air.

By taking the first values in the horse-power formulae and dividing, $144 \div 33{,}000$, we obtain a constant .436, which if divided into the horse-power given will be the mean effective pressure developed in compressing the air.

The formula for calculating the temperature of the discharged air is

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}}$$



where T_2 = final temperature in Fahrenheit degrees.

T_1 = temperature of intake air in Fahrenheit degrees.

P_2 = final air pressure.

P_1 = atmospheric or intake pressure.

n = exponent of compression curve curve and taken as 1.4.

The pressures and temperatures are absolute and must be subtracted or added, as the case may be, to 14.7 pounds and 460.7°. In the curves and tables, T_1 is assumed as 70° and that the air is cooled to 70° between each

stage of compression. As the cylinders should be proportioned to do the same work in each, the temperature resulting at the end of compression in each should be the same.

The temperature in degrees Fahrenheit will be found inside the margin on the left side of the diagrams.

TWO STAGE

Gage Pressure	Absolute Pressure	No. of Atmospheres	H. P per cubic ft. of Free Air	H. P. + 15 % for Friction	M. E P.	M. E. P. + 15%
50	64.7	4.40	.1063	.1225	24.30	27.90
60	74.7	5.08	.1184	.1360	27.20	31.30
70	84.7	5.76	.1286	.1478	29.50	33.90
80	94.7	6.44	.1372	.1580	31.45	35.20
90	104.7	7.12	.1462	.1685	33.55	38.50
100	114.7	7.80	.1542	.1770	35.40	40.70
110	124.7	8.48	.1615	.1855	37.03	42.60
120	134 7	9.16	.1681	.1935	38.80	44.60
130	144.7	9.84	.1740	.2010	39.90	45.70
140	154.7	10.52	.1810	.2080	41.52	47.75
150	164.7	11.20	.1865	.2145	42.75	49.20
160	174.7	11.88	.1912	2200	43.80	50.50
170	184.7	12.56	.1968	.2260	45.10	51.85
180	194.7	13 24	.2015	.2310	46.17	53.10
190	204.7	13.92	.2068	.2380	47.28	54.35
200	214.7	14.60	.2110	.2425	48.30	55.65
210	224.7	15.28	.2155	.2470	49.35	56.70
220	234.7	15.96	.2196	.2525	50.30	57.70
230	244.7	16 64	.2240	.2570	51.30	59.10
240	254.7	17.32	.2280	.2620	52.25	60.10
250	264.7	18.00	.2315	.2660	53.10	61.15
260	274.7	18.68	.2350	.2700	53.85	62.05
270	284.7	19.36	.2385	.2740	54.60	62.90
280	294.7	20.04	.2420	.2780	55.50	63.85
290	304.7	20.72	.2455	.2820	56.20	64.75
300	314.7	21.40	.2490	.2860	57.10	65.70
310	324 7	22.08	.2520	.2900	57.80	66.50
320	334.7	22.76	.2550	.2940	58.50	67.40
330	344.7	23.44	.2580	.2975	59.20	68.20
340	354.7	24.12	.2610	.3010	59.90	68.95
350	364.7	24.80	.2640	.3040	60.60	69.85
360	374 7	25.48	.2670	.3070	61.30	70.50
370	384.7	26.16	.2695	.3100	61.90	71.30
380	394.7	26.84	.2720	.3130	62.40	71.75
390	404.7	27.52	.2745	.3160	62.90	72.30
400	414.7	28.20	.2770	.3190	63.60	73.20
410	424.7	28.88	.2795	.3215	64.10	73.90
420	434.7	29.56	.2820	.3245	64.70	74.50
430	444.7	30.24	.2845	.3270	65.30	75.20
440	454.7	30.92	.2870	.3295	65 80	75.75
450	464.7	31.60	.2895	.3320	66.30	76.30

L. L. Willard

THREE STAGE

Gage Pressure	Absolute Pressure	No. of Atmospheres	H. P per cubic ft. of Free Air	H. P + 15% for Friction	M. E. P.	M E P. + 15%
100	114.7	7.8	.1450	.1670	33.30	38.30
150	164.7	11.2	.1752	.2018	40.30	46 50
200	214.7	14.6	1965	.2260	45.20	52.00
250	264.7	18.0	.2140	.2460	49.20	56.60
300	314.7	21.4	.2295	.2640	52.70	60.70
350	364.7	24.8	.2418	.2775	55.45	63.80
400	414.7	28 2	.2535	.2915	58.25	66.90
450	464 7	31.6	.2630	.3016	60.40	69.40
500	514.7	35.0	.2730	.3140	62.30	71.70
550	564.7	38.4	.2830	.3255	65.00	74.75
600	614.7	41.8	.2910	.3345	66.85	76.90
650	664.7	45.2	.2960	.3405	67.90	78.15
700	714.7	48.6	.3025	.3480	69.40	79.85
750	764.7	52.0	.3090	.3550	70.75	81.40
800	814.7	55.4	.3150	.3620	72.45	83.25
850	864.7	58.8	.3210	.3690	73.75	84.90
900	914.7	62.2	.3260	.3750	74.80	86.00
950	964.7	65.6	.3315	.3814	76.10	87.50
1000	1014.7	69.0	.3360	.3826	77.20	88.80
1050	1064.7	72.4	.3400	.3910	78.10	90.10
1100	1114.7	75.8	.3445	.3965	79.10	91.10
1150	1164.7	79.2	.3490	.4015	80.15	92.20
1200	1214.7	82.6	.3525	.4052	81.00	93.15
1250	1264.7	86.0	.3570	.4115	82.00	94.30
1300	1314.7	89.4	.3615	.4160	82.90	95.30
1350	1364.7	92.8	.3660	.4215	84.00	96.60
1400	1414.7	96.2	.3685	.4235	84.60	97.30
1450	1464.7	99.6	.3710	.4265	85.30	98.20
1500	1514.7	103.0	.3740	.4300	85.80	98.80
1550	1564.7	106.4	.3780	.4345	86.80	99.85
1600	1614.7	109.8	.3820	.4385	87.60	100.8
1650	1664.7	113.2	.3850	.4430	88.40	101.8
1700	1714.7	116.6	.3880	.4460	89.10	102.5
1750	1764.7	120.0	.3915	.4500	89.75	103.2
1800	1814.7	123.4	.3940	.4530	90.50	104.0
1850	1864.7	126.8	.3965	.4560	91.15	104.8
1900	1914.7	130.2	.3090	.4600	91.80	105.7
1950	1964.7	133.6	.4020	.4625	92.25	106.2
2000	2014.7	137 0	.4050	.4655	93.00	106.9
2050	2064.7	140.4	.4075	.4680	93.50	107.5
2100	2114.7	143.8	.4100	.4715	94.10	108.2

L. L. Willard

AUTOMATIC APPLIANCE FOR STOPPING AND RE-STARTING MINE CARS

In a paper read recently before the North of England Institute of Mining and Mechanical Engineers Mr. W. Galloway describes an automatic appliance for stopping and re-starting mine cars. This appliance has been installed at a colliery in South Wales, and successfully operated for more than a year, the weighing on the surface, and the loading and unloading of the cages at the top and bottom of the shaft being automatically effected without a hitch during this period. At Garth the appliance is worked by means of compressed air, but steam can be used and the details varied in many ways. As applied to weighing, the operation is as follows:

The axles of the full car, running at any velocity less than that required to overturn it, successively depress and pass over a pair of catches, which immediately rise up behind them. No sooner is the hinder axle clear of these, than the front axle, coming in contact with and pressing against another pair with the full force due to the momentum of the car, pushes the frame of the appliance and its connections, including the piston within a com-

pressed air cylinder, to a greater or less distance in the same direction from a few inches to a foot, according to the greater or less velocity at which the car has been moving. But the pressure of the air within the cylinder, now acting like a spring, arrests the forward motion of the car and then draws it back until it stands directly over the center of the weighing platform. The operation of weighing having been completed, the weigher places his foot on the foot-plate, and thereby opens a valve by which the air-pressure is withdrawn from the right-hand side of the piston, and the latter, together with the frame, is pushed toward the right-hand side and the first pair of catches, pressing against the hinder axle of any car that happens to be in front of them, drive it forward at a greater or less velocity, according to the size or diameter of the cylinder and the higher or lower pressure of the air acting on the piston. When the frame has nearly reached the end of its intended stroke, a spring fixed to the weighing platform arrests the forward movement of the rod: the second pair of catches are thereby depressed, and the car continuing to run forward after the frame has come to a standstill, passes over them, and proceeds toward its destination. As soon as the hinder axle of the car is clear of the catches, the weigher removes his foot from the foot-plate, the valve closes automatically, the pressure of the air on the right-hand side of the piston is restored and the frame is drawn back to its original position, ready to receive another car. The rapidity with which the frame is drawn back depends on the area of the opening of a valve. The frame is covered with a sheet of iron to prevent coal or rubbish from falling into its interior, and the only openings in it are those through which the catches project. The points to be specially noted are that the moving cars are arrested gently, held in the desired position, and again discharged with the required velocity without muscular effort on the part of an attendant, and that, thereby, a substantial saving in both time and labor is effected. The average rate at which cars, each carrying 1 ton, can be stopped, steadied, weighed, and disposed of by this apparatus in the manner described is six per minute, or, more accurately, one car per 9.58 seconds. The time occupied in pushing a full or empty car of the same capacity into the cage, and thereby discharging the empty or full car in front of it, is about 3 seconds.

FOUR STAGE

Gage Pressure	Absolute Pressure	No. of Atmospheres	H. P. per cubic ft. of Free Air	H. P. + 15% for Friction	M. E. P.	M. E. P. + 15%
300	314.7	21 40	.2195	.2520	50.25	57.80
400	414.7	28.20	.2430	.2795	55.80	64.20
500	514.7	35.00	.2600	.2990	59.70	68.70
600	614.7	41.80	.2750	.3185	63.15	72.60
700	714.7	48.60	.2885	.3320	66.25	76.25
800	814.7	55.40	.3000	.3450	68.80	79.25
900	914 7	62.20	.3100	.3565	71.20	82.00
1000	1014.7	69.00	.3195	.3675	73.35	84.50
1100	1114.7	75.80	.3285	.3780	75.50	86.80
1200	1214.7	82.60	.3350	.3855	77 00	88.50
1300	1314.7	89.40	.3415	.3925	78.40	90.20
1400	1414.7	96.20	.3485	.3985	80.10	92.15
1500	1514.7	103.0	.3560	.4080	81.75	94.00
1600	1614.7	109.8	.3610	.4150	82.85	95.35
1700	1714.7	116.6	.3660	.4215	84.10	96.75
1800	1814.7	123 4	.3710	.4270	85.20	98.10
1900	1914.7	130.2	.3750	.4320	86.15	99.10
2000	2014.7	137.0	.3800	.4375	87.30	100.4
2100	2114.7	143.8	.3840	.4420	88.25	101.5
2200	2214.7	150.6	.3880	.4470	89.15	102.5
2300	2314.7	157.4	.3930	.4520	90.30	103.6
2400	2414.7	164.2	.3970	.4570	91.20	104.8
2500	2514.7	171.0	.4010	.4620	92 10	105.0
2600	2614.7	177.8	.4050	.4660	93.00	106.9
2700	2714.7	184.6	.4085	.4700	93.85	107.9
2800	2814.7	191.4	.4120	.4740	94.60	108.8
2900	2914.7	198.2	.4150	.4775	93.30	109.8
3000	3014.7	205.2	.4180	4810	86.10	110.7
3100	3114.7	211.8	.4215	.4845	96.60	111.4
3200	3214.7	218.6	.4250	.4880	97.40	111.9
3300	3314.7	225.4	.4285	.4910	98.30	113.0
3400	3400.7	232.4	.4315	.4950	99.20	114.0
3500	3514.7	239.0	.4340	.4990	99.80	114.9
3600	3614.7	245.8	.4355	.5015	100 0	115.0
3700	3714.7	252.6	.4385	.5045	100.8	115.8
3800	3814.7	259.4	.4410	.5070	101.2	116.3
3900	3914.7	266.2	.4430	.5100	101 8	117.0
4000	4014.7	273.0	.4450	.5120	102.3	117.5
4100	4114.7	279.8	.4480	.5150	103.0	118.3
4200	4214.7	286.6	.4510	.5180	103.6	118.9
4300	4314.7	293.4	.4525	.5210	104.0	119.5

L. L. Willard

A LONDON FIRE WAGON OF NOVEL DESIGN

Has a Sliding Fire Escape and Compressed Air Plant and a Speed of 31 Miles per Hour

One of the most recent acquisitions of the London County Council Fire Brigade is a 50 horse-power gasoline vehicle, of novel design and extreme usefulness. It is not a fire engine, but a first-aid appliance, which can do much toward the saving of life and property before a fire has fairly got hold of the premises.

This machine carries a "sliding carriage" fire escape, capable of reaching to the height

of 55 feet when fully extended, and it has, in addition to the regulation boxes of tools and hose, a compressed air plant for extinguishing small fires.

This latter is capable of throwing a jet of water under a pressure of 150 pounds per square inch. It is not a chemical machine, but simply consists of a cylindrical water drum of 60 gallons capacity, which can be coupled up to a steel cylinder containing air compressed to about 2,000 pounds per square inch. There is a compressed air cylinder on each side of the water drum, each cylinder being approximately capable of discharging the drum twice, and the drum can, of course, be replenished very quickly from the nearest hydrant. The fire-escape itself is mounted so that it can be very rapidly unshipped, and even the operation of replacing it on the chassis only occupies about thirty seconds.

Ordinary semi-elliptic springs have been used for the suspension of the chassis, but shackles have been abandoned in favor of sliding guide-blocks for attaching the ends of the rear springs to the frame. When fully loaded, and with the men on board, the total weight is about 4 tons 15 cwt. It has a wheel base of 11 feet 6 inches, and measures over all 21 feet.

In a trial run recently in hilly Kent, over a distance of about 50 miles, the results were highly satisfactory, a speed of 31 miles per hour being maintained when necessary on the up-grade.

NOTES ON GREAT TUNNELS.*

By Lewis M. Haupt.
Prof. of Civil Engineering, Franklin Institute.

Tunnels, like bridges, are engineering devices for overcoming physical obstacles to traffic.

Although of ancient origin their recent great development is the outcome of the demands of modern civilization resulting from the increase in population and commerce.

The advent of railroads in 1827 gave an impetus to the building of tunnels to save time, distance and grade in the interchange of traffic. These "horizontal wells," as they were called, were excavated by hand labor, as they were comparatively short, but with the increase of tonnage and demands for greater economy in cost and time, more pretentious enterprises were undertaken, requiring the use of machinery and power for their completion. Thus the ingenuity of man was impressed to meet the difficult requirements of providing an unobstructed passageway through mountains or under rivers or city streets, in the least time and at a moderate cost.

It was not until tunneling machinery was reasonably perfected that long tunnels without shafts became at all practicable for transportation, although there were several constructed at enormous waste of time and labor, for drainage purposes.

The introduction of efficient drills may be said to date from the first American patent, issued to J. J. Couch, March 27, 1851, for a reciprocating, hollow piston-rod, working in a cylinder, operated by steam, but it had a constant feed and no provision for the rotation of the bit. He took out a second patent November 3, 1852, for some improvements, but in the meantime Stuart Guynn was busy on independent lines in applying the same idea in a practical machine,—also having a constant feed,—but it slumbered from 1851 until the contractor of the Hoosac Tunnel, in Massachusetts, Herman Haupt,* embodied with this hollow piston-rod an automatic feed and rotating device which produced a simple, light and effective drill capable of piercing granite at a rate of one inch per minute and weighing only about 125 pounds. In ordinary shale the speed was doubled. It was estimated that with this tool a progress of twelve feet per twenty-four hours could be made at a cost of $16.33 per lineal foot of single track (15x18), or at about half the price of hand work, and with four times the speed.

To prevent the loss of time in clearing the heading from the debris and gases incidental to blasting—as well as to facilitate the drilling of the holes—a system was devised by the contractor whereby the drills were mounted in series of three or four on columns, which served both as supports and feed pipes for power (steam or compressed air). Thus mounted the drills had a large range in altitude or azimuth. The jacks for clamping the staunchions in position and the ball and socket joint at the bottom of frames enabled the

*A paper read before the Franklin Institute, revised for publication.

* Died December 14, 1905.

bits to be readily changed without removing the gang. The plant also included a low counterpoised derrick and truck, enabling the gangs of drills to be rolled to the rear of the heading, which was driven at the bottom. Prepared cartridges were placed in the holes, and held by a plug, wired in series, and discharged by a hand battery, simultaneously. A vacuum fan and conduit laid on the floor soon relieved the heading of foul gases, and the drills were rolled forward, set up, coupled and started without awaiting removal of debris. To protect men and machinery a section of heavy timbers laid on the floor was hoisted by a bell-crank lever to an upright position to serve as a screen during blasting. These several features are clearly shown in Figs 1 to 3, which also illustrate the auxiliary steam plant with tender, when that motor is found to be more expedient.

Modification of this pioneer rock drill were made by Burleigh, DeVolson Wood, and others, to adapt them to the ever varying requirements of the service, and have led to the extensive manufacturing plants of the Ingorsoll-Rand, and other companies for supplying complete outfits of tunneling and mining machinery now in common use for all classes of excavations in hard materials.

The contract price for this tunnel was $2,900,000, while the cost was $50 per lineal foot, or for the full length nearly $1,300,000. It was the purpose of the contractor not to use a shaft but to drive from the ends on a rising gradient and ultimately, when the traffic increased sufficiently, to open a parallel tunnel by means of galleries from the first, at frequent intervals, thus greatly reducing the cost, improving the ventilation and avoiding lining. The State, however, saw great political possibilities in this enterprise, and by a change of administration, during the civil war, its control was assumed by the Commonwealth, the dimensions were changed to double track, a large dam built for power, and other radical departures made, which swelled the cost to about $10,000,000, or five times the amount of the original contract. A shaft was sunk 1,028 feet in depth, which was of little use in expediting the work and was of doubtful utility. This Hoosac Tunnel of five miles in length, the longest in the United States at the time, was simultaneous with that under Mt. Cenis, where a compressed air plant, operated by water-power, was installed by Mr. Sommellier, the experience from which was a factor in the designing of the plans for the Hoosac, and this in turn, for works of the present day. The close relations of the several long railroad tunnels will become more apparent by a brief chronological statement of their statistics and time of construction.

1. HOOSAC, MASS.

Work was commenced in 1854 and prosecuted by private contractors until the State took possession, September 4, 1862. It was enlarged, and completed July 1, 1876, when it was officially accepted. The total cost of the railroad and tunnel, forty-four miles, was $17,322,019, of which $3,287,835 was interest. The progress was greatly accelerated by the introduction of power drills, 1867, and of nitroglycerine, in 1870, which was manufactured by Geo. W. Mowbray, in the vicinity of North Adams. This gives an average progress of 5.5 feet per diem.

2. MT. CENIS* THE ALPS.

The project was first broached by Guisseppe Medail, a Swiss peasant, in 1838, and subsequently, in 1852, M. Colladou suggested driving it by the use of compresed air drills, operated by water-power, but it was not until 1857, after a report by experts, that the Piedmontese Parliament granted a charter and agreed to pay half the estimated cost, which was $7,760,000, but it ultimately paid for the entire work.

The first blast was fired August 18, 1857, and the headings met December 25, 1870. It was opened for use September 17, 1871. It was double-track, driven with bottom heading 9½x8½ feet. Average rate of progress, 8.00 feet per day. Total length, 42,158 feet, or 8.0 miles. Time, fourteen years in building. Cost, $14,498,352. Machine drills were introduced at the north end in 1861 and at the south end in 1863. The last year the rate was 14¾ feet per day.

3. SUTRO TUNNEL.

The third long tunnel built was designed to open up the famous Comstock lode, in Nevada, by providing better drainage and greater accessibility to the mines. The section was 12x16 feet and length 20,351 feet, or nearly four miles. Work was begun October 19, 1869, and completed about 1878. There were four shafts designed to be used in construction, three of which were over 1,000 feet deep, but two of

* Drinker's Tunneling, p. 266.

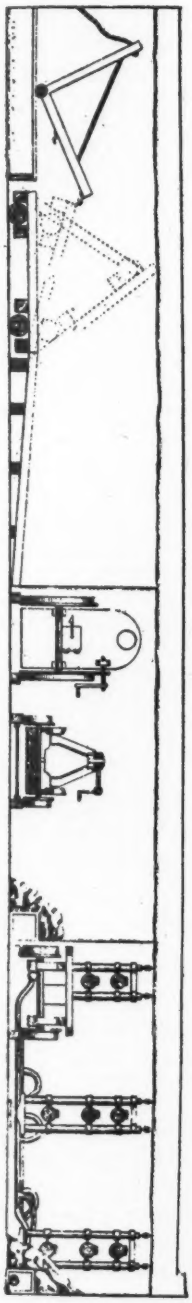


Fig. 3

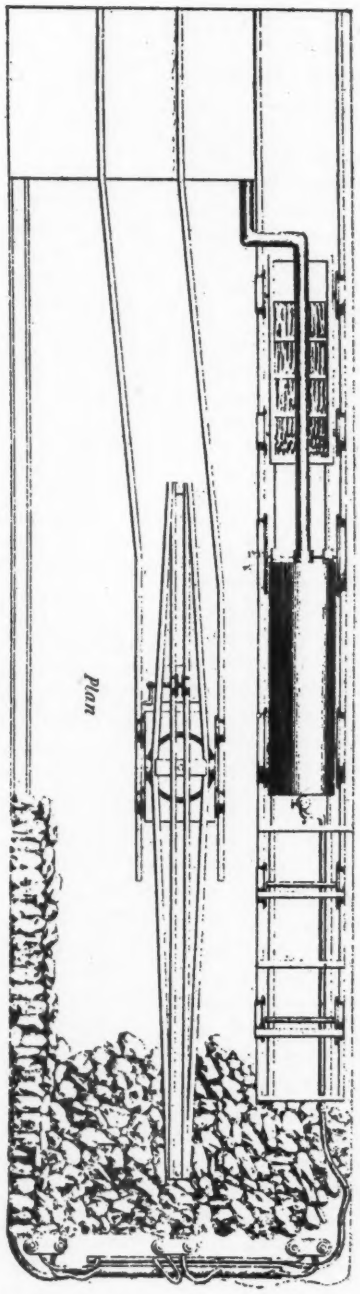


Fig. 2

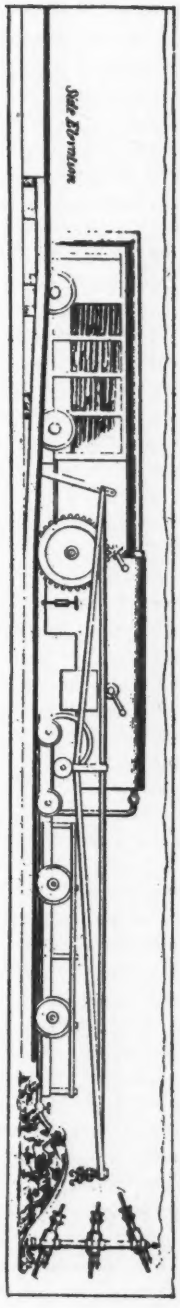


Fig. 1

them were abandoned before reaching grade because of the great influx of water. Progress per day (1875) in heading (10x8) was 10.24 feet.

4. ST. GOTHARD. ALPS (1872-81).

At the St. Gothard tunnel the Sommellier drills were used for a few years but were supplemented by those of McKean & Ferroux, making about 180 blows per minute. These McKean drills were modifications of the system designed for the Hoosac Tunnel and taken to Europe by Blanchard & McKean, agents for the contractor.

The contract for the St. Gothard was awarded to Mr. Louis Favre, August 7, 1872, at an estimated cost of $10,000,000, and was completed in eight years, with a premium of $1,000 per diem for every day saved or a similar penalty for each day lost. With the system of rapid firing and removal of debris great progress was made in each heading, and the work was opened in 1880—the first train passed through in 1881.

Its total length is nine and one-quarter miles; time, nine years, five months, and average daily progress, 14.6 feet, notwithstanding great difficulties from water and the caving of the lining. The early location of the approaches was placed high on the mountain slopes instead of the valley bottom, adding much to the expense, but this was afterward modified by the use of the spiral tunnel and loops.

THE ARLBERG TUNNEL. ALPS (1880-84).

Through the Austrian Tyrol a tunnel of 6.38 miles was driven between 1880 and 1884 at a much more rapid speed than any of its predecessors, at an estimated cost of $7,000,000. The time consumed was three years, nine months, and the average rate of progress 27.8 feet per diem. Work was conducted very systematically and construction trains were run by time schedules. The headings, which were 7.5 feet high and 9.2 feet wide, were placed at the bottom instead of the top of the tunnel. In cost, therefore, this work was but $1,000,000 per mile, $208 per foot, and in speed of execution three times as fast as Mt. Cenis.

THE SIMPLON. 1893-1905. 12¼ MILES LONG.

This tunnel, which connects Brig, in the Valley of the Rhone, with Iselle, on the Diveria, in Italy, is twelve and one-quarter miles in length. The contract was let in September, 1893. The plans contemplated the use of the system proposed for Hoosac of two single-track parallel tubes 16.5 feet wide, 55.7 feet apart, but connected by oblique galleries at frequent intervals. Only one of them was to be completed to full dimensions, while the second was to be used for subsidiary purposes to provide trackage for construction and ventilation, and to await the demands of traffic for its final enlargement. The cost is reported to be $15,500,000 to February 24, 1905, when the headings met, thus opening the shortest route by eighty miles between Paris and Milan, and connecting the Atlantic and the Mediterranean. The large amount of water and high temperature (reaching 118°F.) made this work one of unusual difficulty.

Actual work was begun in 1898, so that the average ratio has been nearly two miles a year, and it is a monument to the enterprise and energy of the countries which have contributed so liberally to the colossal work which at best will save but a few hours in transit between the Italian seaports and the British Isles. (For difficulties from hot springs see Scientific American of March 18 and 25, 1905).

SUBWAYS.

The feature of the above works is that they have generally been excavated from the ends, without intermediate shafts or slopes. Many more miles of continuous underground ways are now in existence, as in the numerous subways of Continental and American cities, but these have been built largely as open cuts or covered-ways, or with numerous shafts.

SUB-AQUEOUS.

Another important class of structures is the sub-aqueous passages connecting great centers of industries and taking the place of bridges. These involve greater difficulties and risks than are to be found in the previous classes, yet to avoid the transfers, delays and risks of ferries or the obstructions due to bridges, ice and fogs, they are found to be expedient, even at very great cost.

The latest and best practice in works of this kind is illustrated in the extensive system of tubes now completed and under construction by the Pennsylvania Railroad Company, under the direct supervision of Mr. Chas. M. Jacobs, Alfred Noble and others, in and across the rivers surrounding the Island of Manhattan, and connecting its western ramification directly with the greatest seaport of the continent, without break of bulk.

Whilst the tube-system as used underneath the North River at New York has required much ingenuity to adapt it to its purpose, the general idea was first applied in the pioneer work built under the Thames, at London, by M. I. Brunel, in 1825 to 1846. This structure is 1,200 feet long, with two passageways 14 feet wide by 16½ feet high, and is now used by the East London Railway.

The influx of mud and water were so great as to cause the invention of a shield to cover the whole face of the excavation, 38 feet wide and 22½ feet high. An attempt was made to introduce the Beach pneumatic system in New York about the year 1863, but it was untimely, and the traffic had not at that time reached such magnificent proportions as to justify the expense, and there was an aversion to being shot through a hole in the ground by the public. Electric motors were not then available. Again, in 1868-69, W. H. Barlow used a modified form of Brunel's shield in building the "Tower" subway under the Thames. This was circular in section, eight feet in outside diameter, and was lined with ribbed cast-iron plates. It was the prototype of the present generally adopted system. In 1889, a pair of tubes, each ten feet in diameter, was laid under the Thames by Mr. Greathead for the South London Railway by means of an improved shield telescoped over the outer end and pressed forward by jacks, as in the Tower subway.

The earliest sub-aqueous aqueduct tunnels in this country were those built at Chicago in 1864-67, two miles long, at a cost of $457,844, and subsequently extended four miles further for a fresh water supply. A second conduit eight feet in diameter and four miles long was added in 1887-1892, and also at Cleveland in 1869-74, when a conduit five feet in diameter and 6,606 feet long was built.

In 1888-1902, the Grand Trunk Railroad built a single-track circular tunnel, lined with cast-iron segments, by the use of shields, under the Detroit River, at Sarnia, through soft clay, sand and gravel 6,000 feet in length. To-day similar systems of sub-aqueous tunnels are being rapidly and successfully built under the North and East Rivers.

AQUEDUCTS.

Still another extensive group of tunnels is to be found in the aqueducts for supplying large communities with water. The most conspicuous example of this class is the Croton Aqueduct of thirty-three miles in length and about fourteen feet in diameter, crossing the Harlem River by means of an inverted syphon at a depth of 306 feet below the surface.

DRAINAGE TUNNELS.

Amongst the most interesting works of this class may be mentioned the ancient Desague de Huehuetoca, undertaken by Enrigue Martinez, a Dutch engineer, in 1607, for draining the basin of the City of Mexico. The tunnel was four miles long and the drain thirteen, but before the lining was completed a great flood caused it to cave in. As a reward for his effort the engineer was imprisoned for three years, and when released he was ordered to make an open cut, in which he spent the rest of his life. But the work was continued for 120 years, yet it was not made deep enough to relieve the basin to any great extent. In 1888, another tunnel was built six miles long and 150 square feet in section, supplemented by twenty-seven miles of large canals, this tunnel had twenty-four shafts, varying in depth from 75 to 325 feet and a discharging capacity of 450 cubic feet per second, and furnishes an excellent precedent for the problem now confronting the Isthmian Canal Commission engaged in the regulation of the floods of the Chagres River at Panama, where the success of the enterprise is made to depend upon the diversion of these torrential waters by means of tunnels from seven to ten miles in length through the Cordilleras. But in this case little is known of the geology or stratigraphy, and as to the possibility of any shafts being used.

Before closing these brief remarks it may be found expedient to glance at the attitude of the traffic problem in this city in 1888 as contrasted with present conditions. Then the necessity of additional facilities was urged by the official publications of this Institute, but was opposed by the vested interests handling the interurban traffic, because of the extreme cost of such works and terminals; of the "impossibility of satisfactorily operating the subway;" because "the subway car motor connected with the other lines of the road;" because "it would be unwholesome and unsatisfactory to the public;" because "it would forever preclude the growth of business on the lines of the company and prevent any extensions in the future to meet increased business," and lastly, because "the destruction of the railroad's terminal facilities in Philadelphia would entail a

loss* impossible to estimate."

That these objections were untenable is evident from the fact that the "impossible" has vanished, and the underground and elevated roads have come to stay. Councils are now considering the necessity of abolishing all grade crossings and the steam routes are cheerfully acquiescing, while the city and railroad engineers are harmoniously working to relieve the surface from all rapid transit trains, as is best for the interests of all parties.

The Market Street subway contracts for sections 3 and 4, extending from Fifteenth Street west to the Schuylkill River, were let to E. E. Smith on April 1, 1903, and the work, which was begun April 6, has been vigorously prosecuted so that it is expected to be open for traffic this year (1905). It is designed for four tracks, two of which will carry express trains to connect with the elevated railroad building out Market Street from the east side of the Schuylkill to Delaware County. The four-track bridge across the river is now well under way. The local or outer tracks will make a loop at the eastern end, passing down Fifth to Walnut, thence to the River Delaware, to Arch, to Fifth and return to Market. The dimensions, in clear, are 48 feet 6 inches in width and 14 feet 6 inches in height from top of rails. The roof girders are supported by three rows of steel columns. The side walls are of reinforced concrete, and the work is being carried on without seriously interrupting local traffic.

Stations are placed at Fifteenth, Nineteenth and Twenty-fourth Streets.

Chicago has already constructed some twenty-eight miles of freight and passenger subways at a rate of twenty-one feet per day from each of the fourteen headings, the material being firm clay (See Scientific American, March 11, 1905) giving the unprecedented rate of progress of twelve miles in less than a year.

Boston has built a much-needed underground transit way, which is very popular and which has to some extent relieved the congestion of the surface, and the great work in New York goes rapidly on, but it is demonstrated that by the time one system is completed the increase of traffic has reached the limit of its capacity and another is demanded, so that to-day applications are being made for new charters under additional streets.

In view of the record of the past it is reasonable to look for the construction in the near future of the long-projected tunnels under the Straits of Dover to connect the British Isles with the Continent by a continuous line of rails, and the project of M. Lobel under Behrings Straits to join Alaska and Siberia, and thus furnish an all-rail overland connection between New York and St. Petersburg or Paris, or even with Cape Town in Africa, via the Cape to Cairo route.

These are some of the transformations which the engineers of the future may effect in the traffic routes of the world, through the instrumentality of great tunnels made practical by improved drilling machinery.

*See Rapid Transit in Cities, Jan., 1888, Journal of F. I. Feasibility of Underground Railroads, Dec., 1888, Journal of F. I.

For further details see "Tunneling," by Henry S. Drinker. Johnson's Encyclopœdia article Tunnels, by Wm. R. Hatboro. Tunneling by Machinery, Herman Haupt, 1867.

THE PANAMA CANAL

Prof. William H. Burr, of Columbia University, recently addressed the American Association for the advancement of science on the work at Panama. Among other things, he said:

"The length of the Panama canal is about 45 miles between 40-ft. contours at low water at its terminal, but the length between shore lines will not be more than 42 miles.

"The topography of the isthmus at the Panama crossing is well adapted to the construction of this ship canal, the original summit of the divide on the line of the canal being but about 330 ft. above sea-level. This has now been reduced to about 170 ft. above mean sea-level by the French excavation at Culebra. About one-half of the length of the canal lies along low marshy ground on either side of the isthmus, making two natural sea-level sections, one about eighteen miles long on the northerly side of the isthmus, and the other about seven miles long on the southerly side; that on the northerly side running for the greater part of its length generally along the course of the Chagres river. This river has been one of the main features in the consideration of the canal work since the beginning of operations by the old Panama Canal Co. in 1881. It is not a large river, as it has not more than about 800 square miles of watershed above Bohio, where in its flow toward the sea it leaves the rising ground and enters what may

be termed the coastal plain, through which it meanders along a sinuous course to the ocean. It has even changed its course in the past at various locations in this marshy ground.

"That portion of the canal route lying in the higher ground of the divide is but about 24 miles long, and but little more than three-quarters of a mile of it had an original surface elevation exceeding 200 ft. The surface material is largely clay of ordinary character, slippery and easily moved when wet, but holding well in place when protected from the entrance of water. Below this covering of clay lies material of irregular character, as the entire isthmus is of volcanic origin. In the continental divide, at a depth varying from 20 to 40 or 50 ft. below the surface, an indurated clay, classed for purposes of excavation as soft rock, is found. This material gives place irregularly to hard rock at greater depths. Much of the rock of the isthmus is soft, although there is hard basalt in a number of places and, in one locality on the Panama slope of the divide, columnar basalt is found.

"The work performed by the old and new Panama canal companies amounted in the aggregate to not far from eighty million cubic yards of all classes of excavation, of which possibly forty million cubic yards at most will be found available for the American construction of the canal, whether a lock plan or a sea-level plan be adopted. This work extends practically over the entire canal route, with the exception of the approach channels in the two terminal harbors, and it is nearly continuous. Over considerable stretches of the higher ground it is little more than shallow cuts through the softer surface materials, but at the great Culebra cut the material which has been excavated varies from the surface clay, readily removed by steam-shovels, to hard basaltic rock, requiring blasting by high explosives before it can be removed. All the material, even the indurated clay, below the softer covering, requires blasting before it can be excavated, although the softer portions need the action of black powder only.

"Except the deep cutting at Culebra, through the summit of the continental divide, the most marked work done by the old French company was the dredging through the low marshy lands from Colon to Bohio. There is at present a strip of partially completed canal about 14 miles long with a bottom width of 72 ft., which may be navigated by vessels drawing 12 to 14 ft., with the exception of a short distance near Colon. Indeed, so much excavation was completed in this portion of the canal, intersecting the Chagres at a number of places, that the waters of that river have abandoned the old bed and now flow through the partially completed canal prism."

PNEUMATIC TOOLS AS APPLIED TO SHIP CONSTRUCTION AND THEIR ADVANTAGES TO SHIPBUILDERS AND ENGINEERS*

BY CHARLES SCHOFIELD.

About three years ago the shipyard managers of the United States decided to ascertain whether pneumatic tools as applied to ship construction were a financial success or not, and what actual advantages accrued from their use. They appointed a committee, instructing them to make the necessary inquiries from the various shipbuilders of America, and report the result of their labors at the next meeting. The paper presented caused more discussion and diversity of opinion than any other topic during the whole session. The reports of the various shipbuilders as returned disclosed a most satisfactory state of affairs, and proved beyond a doubt that pneumatic tools as applied to ship construction were a known quantity and beyond the experimental stage. The information thus obtained was not only interesting but instructive to the members generally.

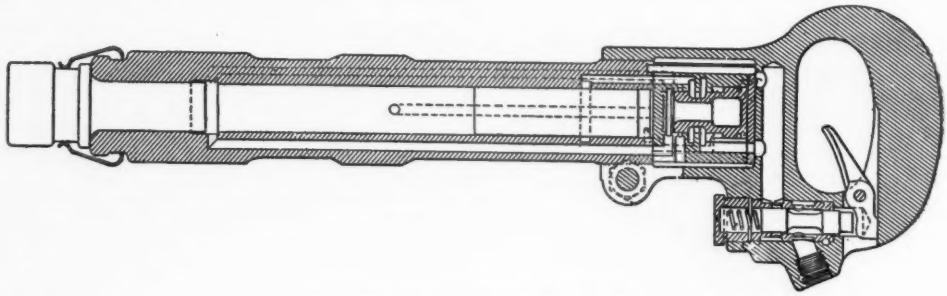
I will endeavor in my paper to explain the methods adopted in the American shipyards as to the application of pneumatic tools in ship construction, also the cost of same, and make a comparison with the British piece-work hand rates.

The first portable pneumatic tools introduced to shipbuilders were shipping hammers. A pneumatic chipping hammer consists of a working cylinder, having attached to it a grasping handle, and inclosing a reciprocating piston and a valve box containing a reciprocating valve. In the lower part of the handle the air-inlet passage is situated, and is controlled by a piston throttle valve arranged

*Read before the North East Coast Institution of Shipbuilders Engineers, November 24. 1905.

therein, adapted to be operated by a pivoted finger lever. The air, after passing the valve, enters the transverse passage, which communicates with an annular groove situated immediately adjacent to the valve box. This groove serves to distribute the air to the various inlet ports and passages in the valve box. The valve box itself is in the form of a hollow cylindrical block bored out to two different diameters to receive the valve corresponding in shape. The valve box is provided with the necessary ports and passages to admit live air to and exhaust from the opposite ends of the cylinder, and for controlling the valve itself in co-operation with the piston. The valve contains no ports or passages, but has two grooves, one cut in the portion of small diameter, and one in that of large diameter. It will be seen that the valve, being made of two diameters, has two pressure surfaces or areas, against the smaller of which air constantly acts to press the valve in one direction; and against the larger area, air under pressure is intermittently admitted through the ports and passages in the valve box and cylinder, those in the cylinder being so controlled by the piston as to move the valve in the opposite direction against the constant live-air pressure on the smaller area. The piston is a solid cylindrical bolt having a groove in its periphery near one end for the purpose of placing in communication with each other the live-air passage, shown in dotted lines leading from the source of supply to the piston chamber, and another passage leading from the piston chamber to the larger area of the valve. The outer end of the cylinder is partly closed by means of an internal ring and the working tools socket. When the working tool is inserted into the tool socket the closure of the end of the cylinder is thereby completed.

In the illustration the valve is in such position that the air is in contact directly with the piston so as to force it forward at high speed until it hits the tool end. When the portion of reduced diameter of the piston comes opposite to the end of the live-air passage, and puts this into communication with the passage leading back to the large area of the valve, the position of the valve is immediately reversed, whereby the live air passes round the groove in the portion of the valve of large diameter into the passage on the opposite side at the front of the piston, forcing the same in a backward direction. The piston on its return stroke cuts off the supply of air from the larger area of the valve, and the latter returns to its initial position, admitting air behind the piston for the next stroke.

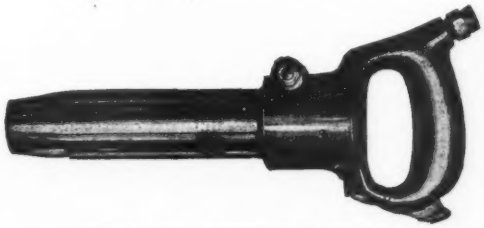


SECTION OF PNEUMATIC RIVETER.

Is was with fear and trembling that we, the shipyard managers, attended the several demonstrations prepared for our edification by the various pneumatic tool companies, as, of course, we were expected to try the tools; and sometimes we thought the piston was taking air at the wrong end on account of the excessive vibration, but this was eventually minimized by the makers adding a little more weight to the hammers. After we had got accustomed to handling the tools and had overcome, to some extent, our prejudice, it became evident to us that the pneumatic chipping hammer had some merit; inasmuch as it could do work in close quarters much better and in less than half the time the same work could be done by hand.

It was, however, months before we could get the men using pneumatic tools to admit

that there was sufficient benefit derived from their use to warrant a reduction from the hand piece-work rate, and it was only by playing our cards diplomatically that we got our first reduction of 40 per cent. on all chipping and cutting, because, at this time, the men experienced great difficulty in chipping a plate edge to a bevel, or when dressing a shell butt, on account of the hammers having round bushings to take the shank of the chisel, whereby the man operating the tool had to twist the chisel as best he could without any resistance from the hammer. But all the up-to-date hammers of to-day have hexagon bushings, and the chisels have hexagon shanks to suit, so that the operator can twist the chisel to any desired angle by twisting the hammer, while a calking iron with a round shank can be used



PNEUMATIC CHIPPING HAMMER.

in the same hammer without the bushing being changed. The current piece-work rate for pneumatic chipping, solid cutting and calking in the United States is about 50 per cent. less than the piece-work hand rates of Great Britain; that is, taking the day-work rates of both countries as a basis. Another feature of the pneumatic calking hammer is that it calks the toe of the gunwale, waterway, tank margin and bulkhead bounding bars without their having been either planed or chipped. This allows the builder to order the said angles the same size as he would if they were not to be calked.

Pneumatic hammers are used extensively by engineers for dressing propeller blades, the palms of struts for vessels with twin screws, bed plates, cutting key ways, cleaning castings, etc., in fact, there is very little hand chipping done in the fitting shops of the American engine builders.

PNEUMATIC DRILLS.

When pneumatic drills were first introduced to shipbuilders they had to compete with electric drills of all sizes and weights; and during a four weeks' test at the works of William Cramp & Sons, of Philadelphia, the pneumatic drills proved their superiority. At the time of the test we were building three cruisers and two battleships, which had protective decks made up of two plates, each 1½ inches thick, connected by 1¼-inch rivets. It was on these plates we made the test, the average for the twenty-four days being as follows:

Air pressure on 12 days, being 90 pounds 248

AIR PRESSURE	Holes Drilled	
	Pneumatic	Electric
On 12 days, being 90 lbs.....	248	100
On 9 days, being 84 lbs.....	232	100
On 3 days, being 76 lbs.....	208	100

The result was that we dispensed with twenty-six electric drills, and took 60 per cent. off the piece-work rate of drilling on this class of work; we also made a reduction of 60 per cent. on the price of holes drilled in the deck plating for deck planking, and took 50 per cent. off all other drilling on the ship, except odd work.

Pneumatic drills are now used for every conceivable purpose by American shipbuilders, among others, cutting out side-light holes, ventilator and coal port-holes in the deck, boring stern-post gudgeons, wood backing for armor-plate bolts, tube cutting, tube expanding, tapping for stay bolts, screwing in stay bolts, and by using a speed reducing gear attached to the drill it is possible to tap up to 4 inches diameter, and to operate this combined machine only one man and a boy are required. In fact, the pneumatic drill is an indispensable factor in connection with speedy and economical ship construction in its various branches.

PNEUMATIC RIVETING.

Probably the hardest manual labor in all the various operations in building a ship is that of riveting. Combined with this is a certain amount of technical skill acquired only by an apprenticeship at the trade. A first class riveter on inside work cannot properly drive shell rivets and *vice versa*, while the boiler riveter, however good he may be at his own work, is of little use on any part of the ship's hull. In addition to this, the rapidly increasing size of ships, with the corresponding necessity for heavier plating, doublings, etc., requires the use of larger and longer rivets, which cannot properly fill the hole when driven by hand, however skilful or willing the men may be.

For all these reasons combined, in the yard of the Cramp Company, of which I was the shipyard manager, some seven years ago a determined effort was begun and an extended series of experiments entered upon to develop pneumatic machinery capable of being operated by unskilled labor, by which all the rivets in the ship could be driven. This effort has been entirely successful, not only at Cramp's but at all the leading shipyards in the States.

I recently sent to the four leading shipbuilders in America a letter asking them to cable me the approximate percentage of the entire number of rivets in the shell of a ship which they were now driving with pneumatic tools.

I received the following cablegrams in reply:

"Eighty-five to ninety."—James Wallace, Managing Director for the American Shipbuilding Company.

"Thirty shell, eighty hull."—Orcutt, President of the Newport News Shipbuilding Company.

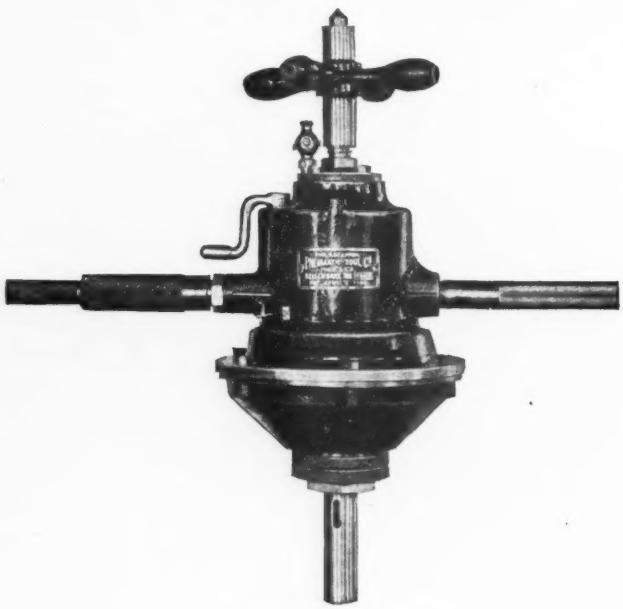
"One hundred."—Wilson, General Manager, Marine Department, The Maryland Steel Company, Sparrow's Point.

"Ninety-nine." Cramps.

The last cablegram was confirmed by letter.

We had in use at that time, a stationary riveter of the ordinary type, driving rivets in such portions of the ship as could be assembled and handled as a whole, namely, frames, water-tight doors, etc., such as are usual in ordinary merchant vessels. A very short experience with compression riveters showed that their great weight—reaching over 2,500 pounds for a six-foot gap—interfered too much with facility of handling to make them either useful or economical.

We then turned our attention to the pneumatic hammer, which delivers an almost continuous series of blows against the end of the chisel, calking tool, or rivet die. The hammer is light, powerful, short enough to go in between frame spacings, and small enough in diameter to get at rivets in corner angles. For rivets up to ¾-inch diameter it can be held in the hand, but for rivets of a larger diameter the hammer should be held in a device suitable to the location of the work on the vessel, for instance, shell device and deck device. It is, however, almost impossible to hold on to the rivet by hand unless a spring dolly bar is used instead of the heavy holding-on hammer used in hand riveting, the heavy holding-on hammer being fairly jarred off the head of the rivet by the rapidity of the blows from the



PNEUMATIC ROTARY DRILL.

pneumatic hammer, giving the holder-on no opportunity to bring his tool back into position between blows as in hand riveting.

PORTABLE PNEUMATIC YOKE RIVETER COMPLETE.

In connection with the above-mentioned pneumatic hammer there is used a simple pneumatic hold-on consisting only of a cylinder carrying a piston, behind which air is admitted, the rod extending through the front head and being cupped out to go over the head of the rivet.

Combining these two machines with a yoke, the hammer being mounted on one arm and the holder-on on the other, makes a self-contained machine in which the yoke can be made very light, as it has to resist only the pressure of the air against the end of the holder-on cylinder, and the reaction of the hammer blows. Various sizes of these yoke riveters are used for riveting the center keelsons, longitudinals, side keelsons, etc. They are also extensively used for riveting certain parts of turrets, gun-carriages, etc., where first-class riveting is absolutely necessary.

For driving rivets in frames and brackets, intercostals and beam knees, etc., we use a jam riveter and pneumatic-holder-on.

The above descriptions will, I trust, make sufficiently plain the methods for driving all rivets that can be reached on both sides by a yoke or jam riveter. There remain three classes of rivets in a ship, as follows: (1) Those through decks and tank tops, mostly countersunk, and all driven downward from above; (2) bulkhead rivets, nearly all with full heads; (3) those in the outside of the vessel and all countersunk. These three classes must be reached by riveters on one side and holders-on on the other, without any connection whatever between them. The first class are most easily driven, and for them the hammer is attached to a universal swivel head, mounted on a pipe or T-bar. The operator raises the hammer to bring the flat die on to the rivet, and the pipe or T-bar being secured at the center, holds the hammer in position while the rivet is being driven. A second man, with a pneumatic chipping hammer cuts off the surplus metal, and the riveting hammer being brought back on the rivet, a few seconds complete the operation. In this case the pneumatic holder-on is operated from below by a third man, being braced against the bottom of the ship or the next deck below.

For the second class, the hammer is simply held in the hands of the operator, said hammer having about a 4½-inch piston stroke, and as the die is cupped out to form the snap point, there is no tendency to slip off the point. The holding-on is done by a spring dolly bar, which I will explain later.

We now come to the third class, or shell rivets, which, in many respects, are the most important rivets in the ship, requiring the most careful workmanship and the best finish. Therefore it is a serious mistake for shipbuilders to attempt to drive shell rivets by pneumatic power until they have established pneumatic riveting on all inside work, because the men operating the tools should be accustomed to handling the hammers before being put on this important part of the work. It is evident at the start that the varying thickness of plates, frame flanges and liners, and especially the depths of countersink render it impracticable to so gauge the length of rivet used that there will always be just enough metal to properly fill the countersink and finish the point, and that, therefore, as in hand riveting, a longer rivet must be used. After the point is beaten down and the surplus metal crowded off to one side, this surplus must be chipped off, and the point be finished up, rounded slightly, and any seams between the rivet and the plate driven together and closed. To do this a certain amount of freedom of motion must be allowed in the hammer, so that its axis may be inclined at a slight angle in any direction with the axis of the rivet itself.

This result is attained by mounting a pneumatic hammer in a device having a universal movement attached to the end of a T-bar, instead of its being immovably fastened to it. For bottom riveting there is a flat bar adapted so as to be mounted on the shell of a ship in any desired position. This bar carries an adjustable support, connected, by means of a swivel joint, with a holder in which is mounted an adjustable frame bar, pivotally supporting at one end a pneumatic hammer, and at the other an adjustable distance piece.

At one setting a space of 14 feet to 16 feet square can be reached with the above device, and when it is necessary to move the device to another position the change can be effected in about ten minutes. A spring dolly bar is used for holding-on, thus dispensing with the costly method of a wood backing, necessary when a pneumatic holder-on was used, as was the case a few years ago, and an ordinary

pneumatic chipping hammer is used to cut off the surplus metal before finally finishing. It is evident that the freedom of movement of the hammer can be secured in other ways, such as a ball and socket joint of large radius, but we have found the above device more satisfactory and all that can be desired.

For riveting the side shell plating the same device is used, with one exception, and this is side the pipe there is a piece of round iron, about 6 inches long, backed up by a spiral spring.

The quality of the work done by all these machines, both inside and outside the shell, is first-class in every respect, and far superior to hand work, seeing that a rivet driven by a pneumatic hammer has to be about 12 per cent. longer than a rivet driven by hand, which goes

	Holes drilled.	
	Pneumatic.	Electric.
Air pressure on 12 days, being 90 pounds	248	100
" 9 " 84 "	232	100
" 3 " 76 "	208	100

Distribution.	No. of Rivets.	Diameter of Rivets. Inch.	Machine Rate, Each. Cents.	Hand Rate, Each. Cents.
Keel (flat)	6,217	1	2½	4½
Shell	21,628	⅞	1¾	3½
Shell margin (bilge single line)	1,122	⅞	3	4½
Longitudinals, open	24,632	¾	1¼	2¾
C. V. K. brackets	3,197	¾	1	3½
" "	.....	..	1¼	3½
" "	.....	..	1½	3½
Longitudinals under tank	664	¾	1¾	2¾
Longitudinals, bars	2,989	¾	1¼	2¾
Tank top stiffeners	1,129	¾	2½	3½
Tank top margin	4033	¾	1½	2¾
Tank top rider	3,209	¾	1¼	2¾
Tank top lugs	1,520	¾	1¾	3½
Tank top	4,467	¾	1¼	2¾
C. V. K. cross vertical keelson	12723	¾	1	3
Hold stringer	1,184	¾	1½	3
Floors	123	¾	1¼	3
Floors (odd)	5	¾	2	6
C. V. K. (odd)	38	¾	2	6
Bulkheads	1,318	¾	1¼	5
"	3,051	¾	1¼	3¼
"	231	⅝	1½	2½
Total	93,480			

TABLE I.

as follows: there is a holder provided with a T-shaped slot, the sides of which form a bearing for the T-shaped frame bar, while allowing said bar to be moved from one position to another in said slot; and a friction spring and set screw, respectively adapted to bear against the bottom of said frame bar when the latter is in position in said slot and to lock the frame bar in any desired position in said holder.

The spring dolly bar now used is made of a piece of 3-inch pipe about 12 inches long, having at one end an ordinary cast-steel handle, while at the other there is a bushing, through which a set screw holds the cup or snap. In-

to prove that the hole is better filled when the work is done by pneumatic tools, and such is the unanimous opinion of the inspectors who have been and are on duty in the American shipyards.

That this is natural appears from several considerations. The rivets are closed down more rapidly and at a much higher temperature, and, as it is always easy to bring the axis of the hammer in line with the axis of the rivet, and, in fact, natural for the men to do so, the rivet is plugged at once by the first blows of the hammer, thoroughly filling the hole throughout before the point begins

to form. The tendency of hand riveters to save labor, to form the point without thorough plugging, leaving a rivet which, though looking all right and passing the tester, is liable to loosen afterwards in service from the constant jar and vibration of the hull, is, therefore, avoided. In many confined places, also, where only one man can strike, and the space for the swing of the hammer is confined to the frame spacing or less, hand rivets are very apt to be poorly driven, but it is evident that such considerations do not affect the machine, and that, if the pneumatic hammer can get to the rivet at all, it is as well put in as in the most open parts of the work.

As to the cost of pneumatic riveting, I submit the figures of Table 1, which are piece work rates current in the States, also figures comparing them with the British piece-work hand rates. In making this comparison, I must call your attention to the fact that both day-work and piece-work rates in America are about 35 per cent. higher than in Great Britain. This is due chiefly to the cost of living being higher. So that the piece-work prices for pneumatic riveting in Great Britain should be one-third less than the prices paid in America.

Table 1 was compiled from an actual test covering a period of three weeks at the Chicago plant of the American Shipbuilding Company.

Total cost of job by hand would have been	$2,986.87
Total cost of job by machine was	1,403.31
Saving of machine over hand work	$1,583.56
Average cost per rivet of hand work	3.19 cents
Average cost per rivet of machine work	1.50 "
Average saving per rivet of machine hand work	1.69 "

Average cost of machine riveting was 47 per cent. of hand cost.

If the above 93,480 rivets had been driven by pneumatic tools in a vessel building in a British shipyard at piece-work rates one-third less than are paid in America, the result would be as shown in Table 2.

The amount that should be added to machine cost to cover interest, maintenance of plant, and operation of compressor, is about 15 per cent. of the gross earnings of the tools.

It is only fair to mention that, at the time the above test took place, about seven years ago, pneumatic tools were not so perfect as they are to-day, and their application to ship construction has been very much simplified. For instance, when driving bulkheads and shell it was customary to use a pneumatic holder-on, which necessitated something to act as a backing for the tool, said backing having to be built up, which added considerably to the total cost of riveting, whereas now a spring dolly bar is used, which the holder-on holds in his hands; again, the shell device for holding the riveting hammer while driving the rivet has been very considerably improved, and can be removed from one position to another on the ship in less than one-fifth the time required to remove the old device.

In conclusion, I should like to say that, while visiting the various shipyards on the Clyde, one of the most prominent shipbuilders called my attention to the fact that since commencing to use pneumatic tools they have turned out 20 per cent. more tonnage, from the same building berths, than they did before. So there is not only a saving in the reduced price of work done by pneumatic tools, but also a great saving in time, which is a very important item to a shipbuilding company which is limited as to space and has not sufficient berths to accommodate all the vessels under order.

Thus it will be seen that, while pneumatic tools are still only in their infancy, there is no limit to the advantages that shipbuilders and engineers can gain by their use in connection with shipbuilding and engineering. In addition to the tools already mentioned, there are now on the market pneumatic hoists, rammers, molding machines, wood-deck calking machines, wood-deck planing machines, painting machines, and large hammers for blacksmith work.

THE SCRANTON TUNNEL OF THE LACKAWANNA AND WYOMING VALLEY RAILROAD

During the years 1901, 1902 and 1903 a double-track, high-speed electric railway was constructed for this company on a private right of way in the heart of the northern anthracite coal field, with termini at Wilkes-Barre on the south, and Scranton on the north, a distance of about 20 miles.

The entrance to Scranton was over a hill on the southern side of the city and, during 1904 and 1905, a tunnel was constructed

through this hill. In a paper recently presented before the American Society of Engineers, Messrs. Geo. B. Francis and W. F. Dennis, members Am. Soc. C. E., mention the following interesting facts relative to the use of compressed air in connection with the work:

The company's plans required two shafts, and the simultaneous excavation both ways from each shaft, and at the ends, thus making six points of simultaneous attack.

It was calculated that from 24 to 28 drills would be necessary, and the requisite air supply was approximated at, roughly, 100 ft. per min. for each drill, at 100 lbs. per sq. in., and the boiler capacity at 20-H. P. to each drill. There was actually installed one 80-H. P. and three 150-H. P. boilers, all being return-tubular with brick arch, cast-iron fronts and iron stacks, making a total boiler capacity of 530 H. P.

The selection of the compressors was governed by the plant on hand, and comprised one Rand straight-line, 16x24-in., of about 600 ft. capacity, two Rand straight-line, 20x30-in., each of about 1,000 ft. capacity. At times all these compressors were run at about 20% more than their normal speed of 110 rev. per min., and, roughly, their combined capacity was increased to 3,000 ft. of air per minute when working at their maximum. The three 150-H. P. boilers provided an ample supply of steam, without the assistance of the 80-H. P. boiler, and the results indicate that the preliminary allowance was high, and that about 15-H. P. boiler capacity in this instance was sufficient to compress 100 ft. of air per minute to the gauge pressure of 100 lbs.

Contributing to this economical boiler capacity was the use of anthracite coal under forced draft from a steam jet, making practically perfect combustion, and a more than usually tight distributing pipeline.

Distribution.	No. of Rivets.	British Pneumatic. Price per 100		Total Cost.			British Hand. Piece-work.		Total Cost.		
		s.	d.	£	s.	d.	s.	d.	£	s.	d.
Keel (flat)	6,217	7	0	21	15	2	11	10	36	15	8
Shell	21,628	5	0	54	1	5	8	8	93	14	5
Tank margin	1,122	8	4	4	13	6	10	0	5	12	2
Longitudinals, open	24,632	3	6	43	2	1	8	6	104	13	9
C. V. K. brackets	3,197	3	6	5	11	10	8	6	13	11	9
Longitudinals under tank.	644	5	0	1	13	2	9	6	3	3	1
Longitudinals, bars	2,989	3	6	5	4	7	9	6	14	3	11
Tank top stiffeners	1,129	7	0	3	19	0	10	0	5	12	11
Tank top margin	4.033	4	2	8	8	0	10	6	21	3	6
Tank top lugs	1,520	5	0	3	16	0	10	0	7	12	0
Tank top rider	3,209	3	6	5	12	4	10	6	16	16	11
Tank top	4,467	3	6	7	16	4	10	6	23	8	0
C. V. K. vertical keelson.	12,723	2	10	18	0	6	8	6	54	1	5
Hold stringer	1,184	4	2	2	9	4	8	6	5	0	8
Floors	123	3	6	0	4	4	8	6	0	10	5
Floors (odd)	5	5	9	0	0	4	11	6	0	0	7
C. V. K. (odd)	38	5	9	0	2	2	11	6	0	4	4
Bulkheads	3,051	4	2	6	7	1	7	0	10	13	7
				£192	17	2			£416	19	1
									192	17	2
Amount saved by machine over hand (British rates)									£224	1	11

TARLE 2.

Whenever a pipe line is to be determined, there is always a balance to be drawn between small size, large friction, and small first cost, and the alternate. Without pretending to any accurate determination of these features, a practical balance for this particular work was to run a main 6-in., sleeve-connected, wrought-iron pipe from the compressor, past the first shaft, and up to the second. This pipe was reduced to 4 ins. between the latter and a receiver at the north portal. A 3-in. pipe carried the line to the bottom of each shaft, and the further extension toward the several faces of attack was by 2-in. pipes resting on the bottom. Temporary connection between the end of each pipe and the drills was made by 50 ft.

of 2-in. rubber hose, distributed to the several drills by 1-in. rubber hose. The main 6-in. pipe line was laid uncovered in the streets, over and parallel to the tunnel, and was laid during hot weather. On account of its position in the street, the pipe, while slightly sinuous in detail, was very nearly straight in its general direction. Expansion bends in the pipe were impracticable on account of its location, and as expansion joints are costly and unreliable, the pipe was laid without any appliance to take up the change of length caused by variation in temperature. The line thus laid gave no trouble in passing through the changes of temperature from summer to winter, and from winter to summer.

The general method of tunneling was to carry the bench and top heading together, with the heading from 50 to 75 ft. ahead. A traveling framework, of half the tunnel width, and with the top at a lower elevation than the top of the bench, was mounted on wheels, which ran on temporary rails. The frame admitted the passage of two cars—one to be run up to the bench at its side, and the other underneath. Either car could be loaded by chutes from the platform, and, at the same time, by shoveling the bench excavation. The connections between the traveling platform and the unexcavated portion of the bench was formed with 4-in. lagging built into a plank 24 ins. wide, thus making a wheel-barrow runway between the face of the bench and the movable platform. The heading spoil was loaded into wheel-barrows, wheeled over the plank and dumped through the chute on the traveling frame, the whole operation being performed without interfering with the loading of the bench spoil.

When it became necessary to blast, the planks were simply loaded on the frame and the latter moved back on its wheels to a safe distance.

The foregoing method seems to be so simple and effective as to be scarcely worth description. Other ways of handling bench and heading material at the same time are advocated; nevertheless, the method outlined seems to the writers to be the simplest and cheapest

A peculiarity of the bench rock, in part of this tunnel, modified considerably, not only the foregoing procedure, but also affected the timbering. That peculiarity was a consequence of the combined hardness and tenacity of the bench material. To break it out required so much explosive that the rock was blown lengthwise of the tunnel with such force as to wreck any permanent timbering erected within 200 ft.. In addition, block-holing the spoil was always necessary after the first blasting. The interruption to the work of loading the heading spoil, caused by moving the traveling frame out of danger, was so serious as to render it impracticable to continue the simultaneous excavation of the heading and bench. The heading material, while requiring timber for permanent support, could be left temporarily unsupported; the support being required, not to hold up an overhead mass, but to prevent and support exfoliation, slabbing and weathering of the material. On account of these features, the heading was worked for a reasonable distance ahead, and the force then dropped back and split the bench in two lifts.

The full section of the tunnel was carried without timber support, to the extent of as much as 300 ft. The timbering was then erected from the bottom, and its full section was completed and packed from the floor of the tunnel.

DRILLING AND SHOOTING.

The longest holes were the cut holes fired first, which were from 8 to 9 ft. long. The widening holes were from 6 to 8 ft. long. The round was counted to make an advance of from 4 to 6 ft.

With two 3¼-in. machines, the time required to drill the holes was generally 7 hours. The total round drilled averaged about 140 lin. ft. The completion of the loading, wiring, firing by battery in series, reconnecting for the successive blasts, and the delay necessary between them for the explosive fumes to be blown out by compressed air allowed to escape for this purpose, consumed varying times, from 30 min. to 2 hours, or an average of, say, 50 or 60 min.

The delay from shooting was greatest in the portion of the tunnel excavated from the shafts. In this portion the fumes seemed to hang and accumulate, not only on the firing side, but also on the other side of the shaft, producing delays in both places.

The explosive was 40 to 50% dynamite, mainly the latter, and the cost per cubic yard, for explosives, caps, wires, etc., for all the excavation, was equivalent to the cost of 3½ lbs. of 40% dynamite.

COMPRESSED AIR SERVICE AT NORWICH, CONNECTICUT.

Most people are familiar with the fact that compressed air is sold in Paris for power purposes, being carried under the streets through pipes. Few people, however, probably know that the same device is now available in Norwich, Conn. This has now passed the experimental stage, and has become one of the city's permanent institutions. Being the only thing of the kind in the United States and the second in the world, a smaller one having first been developed in Canada, the results of the experiment are being watched by inventors, possible patrons and investors in most of the cities of this country and many outside.

Air for the system is compressed in a Taylor Hydraulic Compressor situated at a point about 3 miles from the city on the Shetucket River and consists of a dam some 20 or 25 feet high and a shaft sunk 200 feet in the rock below the dam, ending at that bottom in an air chamber extending 100 feet up the river. This chamber being made as near air-tight as possible, the entire stream is conveyed to the bottom through a 10-foot iron pipe, on the top of which are suspended about 1,000 tubes projecting a few inches above and about five feet below the surface of the water. The falling water draws air through these tubes and carries it to the bottom of the shaft, where it is separated and directed into the chamber, while the water returns to the surface outside the pipe and is discharged into the stream, the fall from the dam giving it the necessary impetus to carry the air to the bottom and the weight of 200 feet of water giving the air its pressure.

This pressure is maintained at 90 pounds and is regulated by a six-inch exhaust pipe which discharges at the surface, projecting a stream of water, vapor and air many rods down the river with a hiss and roar that drowns every other sound in the vicinity. A Bristol recording pressure gauge displays the 24-hour record, and so well does the exhaust pipe perform its duty that the little red tracer on the dial describes an almost perfect circle. From the chamber a 12-inch iron pipe delivers the air to the city, and in spite of possible leakages, friction and use, the gauges at the city factories show little variation from a continuous pressure of 89 pounds. The loss, therefore, in conveyance to and distribution over the city is practically nothing, and as 90 per cent. of the theoretical power of the stream is found to have been carried into the chamber, this would seem the most perfect method for transforming and conveying power yet devised.

From a stream of 2,000 theoretical horse power this method is said to deliver 1,800 to the consumer at least three miles away, and the lengthening of the pipes to New London is in contemplation. As the demand for this power increases and exceeds the capacity of the present plant, more may be installed above and below on the same stream and at far less expense than the cost of the first one, said to have been between one and one-half millions. The projectors believe the capacity of the stream will equal any possible demand of both Norwich and New London.

The compressed air is sold at the rate of $3.00 per horsepower per month, but this price may be materially reduced as the power comes into general use.

Liquefaction of air is advantageously effected when the air is initially at its critical pressure of about 40 atmospheres, and is cooled by the circulation around it of air which has been cooled by expansion, but to no great extent. An arrangement described by M. G. Claude in *Comptes Rendus* is this: A tube is connected with two liquefiers and an expanding chamber; compressed air is led into this, some going to fill the liquefiers and the remainder passing into the chamber, where it is expanded to fall only to about 160 deg. Cent., passing then round the first liquefier wherein it produces liquefaction at 140 deg., to which temperature it rises itself, then passing on through a second similar expanding chamber, whereby it again falls to 160 deg., afterwards circulating round the second liquefier and acting on it as before, and finally passing away round the inlet tube and so cooling the entering compressed air. By this method 850 c.cm. of liquid air have been obtained per h.p. hour.

An innovation is a machine which takes in the heated bar of iron and makes the links either interlocked or separate, making 100 to 120 links of 5/8-inch chain per hour. It is claimed that the machine made chain is 20 to 25 per cent. stronger than chain made by hand from the same bar material.

THE REDFIELD PNEUMATIC LOG-SAWING MACHINE

The saw, complete, consists of an engine, frame and saw blade. The constructive details of the machine are such, that although light in weight it is exceedingly strong and durable.

The frame serves as a hanger, and is provided with an adjustable hook to grip any size log, and requires no other support. On each side of the frame is a bar with a spring and roller attachment, the roller being applied on top of saw blade, acting as feed and guide to blade. The weight of frame complete is 85 pounds. The frame is manufactured in two sizes suitable to cut 16 in. and 24 in. lengths.

The 16 in. frame is suitable for cutting logs and stove wood, and since the engine can be operated on each side of the frame, two cuts can be made in one setting. The 24 in. frame is suited to the cutting of locomotive wood, shingle bolts, etc. An ordinary 5′-0″ to 8′-0″ drag saw is used in connection with this device. Owing to the adjustability of the frame, and oscillation of the engine, the saw can be operated in any position relative to the log. The frame can be raised or lowered in an instant.

The engine is constructed entirely of solid drawn brass and steel tubing. Its main feature —in addition to its weight (65 pounds)—is the tubular valve, which is perfectly balanced under all conditions, permitting the engine to work in any position. The valve motion and running gear are simple and easily repaired, hence, there is no complication of valves and parts. The tubular valve is actuated by a rocker arm that raises its motion from two cams fastened to the guide rod.

PNEUMATIC LOG SAWING MACHINE.

Weight of frame 85 pounds.

Weight of engine 65 pounds.

Capacity of saw in logs 500 per day of 10 hours.

Twenty cords of 4-foot wood or ten cords of 2-foot wood per days of 10 hours.

Ordinary working pressure required 75 pounds.

Normal number of strokes per minute 65.

Maximum number of strokes per minute 150.

Cubic feet of free air consumption at 65 strokes per minute, 33.

COMPRESSED AIR

Established 1896.

A monthly magazine devoted to the useful applications of compressed air.

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MANY of our readers probably noticed a very obtrusive and, what must seem to them, inexcusable error which appeared at the close of our editorial, entitled "Are We Being Superseded," in the last issue of COMPRESSED AIR. This was nothing less than the omission of the sub-figure 2 in our abbreviation of carbon dioxide. We hasten to assure them that the error was not our fault, in fact, we did everything in our power to correct it. We noticed it in the first proof submitted to us and made the necessary correction. When the page proof arrived, however, the same error was in evidence, the type-setter evidently considering it beneath his dignity to trouble himself in such a small matter. We accordingly made the correction a second time and very foolishly marked the proof "O. K. as corrected" with the result that the correction never was made and the writer found himself in the enviable position of not appearing to know the difference between carbon monoxide and carbon dioxide (kindly notice that we do not venture to use chemical symbols a second time but content ourselves with plain English).

PROF. HAUPT ON TUNNELS

We publish from the Journal of the Franklin Institute some interesting notes on tunnels written by Professor Haupt. These notes are in very concise form and embody a good deal of valuable tunnel information, particularly with reference to progress and costs. Professor Haupt is qualified to speak understandingly. His father, General Herman Haupt was the engineer of the Hoosac tunnel in Massachusetts, five miles in length, begun in 1854, and generally spoken of as the first tunnel to use machine drills in its construction. The Hoosac tunnel showed the possibility of drilling rock by machinery, though it cannot be said that the rock drills used there were a success because of the extraordinary expense in repairs, which it was said only the State treasury of Massachusetts could stand. Since the days of the Hoosac tunnel the perfection of the air drill has resulted in extensive tunnel construction, the most notable instance being that of the Simplon tunnel in Switzerland, recently completed. Two systems are in use for driving tunnels by machinery—one known as the European system, by means of which heavy drills are mounted on carriages in headings, and the American system, which involves light drills mounted on columns which are jacked in the headings. It is worthy of note that in the case of the Simplon tunnel the European system has been modified and perfected to a point of extreme simplicity. The old cumbersome tunnel carriage which occupied nearly the entire area of the heading has been abandoned and a small carriage used which is no longer than a wheel-barrow and which carries a horizontal shaft bar operated by hydraulic power. The drills used in the Simplon tunnel were hydraulic machines of 30 H. P. capacity each. From 4 to 6 machines were mounted on this horizontal bar and the drilling of the holes was done in most instances with a single location of the bar in the heading; that is, this bar carrying the drills was lifted hydraulically until it reached a point approximately the center of the heading, when through hydraulic power it was jacked against the walls of the tunnel and the

holes were put in at varying angles by swivelling the drills upon the bar. To do this, following the American system, would be out of the question as the holes when blasted would not bottom properly, but it worked successfully in the Simplon tunnel because the system there involved holes of 3 inches in diameter and from 3 to 4 feet only in depth. Obviously the deep hole such as we use in America in the headings, and which bottoms from 8 to 12 feet from the face, involves more care as to the exact angle at which the hole is to be put in than a hole of shallow depth. If the shallow hole will serve the purpose a great deal of time and expense is saved. Another point of advantage in the shallow hole of large diameter is that when blasting it throws the rock some distance from the heading. At Simplon they were not troubled by the extensive banking up of the muck near the heading because blasts were frequent, sometimes two and three a shift, and it was usual to run three 8-hour shifts. The shallow holes of large diameter were loaded almost to the muzzle and the rock was so scattered that it was an easy matter to bring the little carriage forward to the heading for another round. The system employed at Simplon, and the use of drills of 30 H. P., is the real reason why such remarkable progress was made there. The popular idea that this progress was due to the use of hydraulic drills is a mistake. It is due in the first place to the system employed, to the use of drills of large horse power, to the hydraulic carriage and mountings, and to the fact that having so long a tunnel to drive (12¼ miles) they reached almost perfection in doing a kind of work which was duplicated from day to day.

The American system exists to-day as it was 25 years ago. The New York Aqueduct, built twenty years ago, the longest rock tunnel ever driven in America, consisted of about thirty-one shafts separated about a mile apart each. The excavation was 16 ft. in diameter of rock section and the machinery used and its mounting was identical with that employed to-day by Messrs Pearson and others in the construction of rock tunnels under the rivers about New York. The one important advance has been in the saving in rock drill repairs, due to better design, material and workmanship in the machines. There has, however, been a distinct tendency toward the use of larger and more powerful rock drills, but there is always the limit of weight to contend with when using the American system of mounting on columns, so that American engineers in their efforts to get better work by the use of larger drills are held in check by the fact that an essential condition of the use of a rock drill in a tunnel employing the American system is that it can be lifted to its place on the column by three or four men. We look for improvement in this line by the adoption of carriages similar to those used at Simplon and by the use of percussive drills of larger diameter. Such a combination would result in the adoption of the shallow hole of large diameter as against the deep hole in the heading, and in this way the problem of mucking would be simplified.

Another improvement in sight is the adoption of the channeling process in headings in place of the cut holes. It has been demonstrated in New York City that it is perfectly practicable by the use of a machine similar to an ordinary rock drill to insert a channel directly across the heading and to a reasonable depth,—in this way making a release line toward which to direct the blasting. The importance of this in tunneling under foundations of buildings cannot be over-estimated. The channel does in a tunnel heading what it has long ago accomplished in stone quarrying; that is, it reduces to a minimum the shock of the blast, which is always greatest when discharging the center cut from the heading.

AIR DRILLS VS. ELECTRIC DRILLS.

Readers of COMPRESSED AIR will probably remember an article by Granville E. Palmer on the comparative merits of compressed air and electric rock drills, which was written for this paper and appeared in the June issue (Vol. XI, No. 4). It may, therefore, be of interest to them to know that the *Engineering and Mining Journal* reprinted this article (without, by the way, givinging COMPRESSED AIR any credit for having published it originally) with the result that a very interesting discussion has been started in its correspondence columns among mining men who have tried both types of drill.

Taken all in all, the general opinion would seem to be in favor of the air drill, although the Temple electric-air drill seems to have met

with considerable favor. This drill, however, as far as the drill proper is concerned, is in reality an air drill in its simplest form and using air expansively. Speaking of this drill, Mr. H. B. Barnes states that the "Temple drill has proved quite satisfactory in the Leadville district, being used in the largest tunneling operations, in which line it has done some remarkable work as is shown by the figures given below.....in drilling a round of holes in a breast of iron and zinc sulphide recently by a Temple 5A drill, the men working at ordinary rate and not under any forced speed."

Hole No. 1.	Cutting Speed.	Power.
1st steel.	4½ in. per min.	4 h.p.
2d steel.	7 in. per min.	3½ h.p.
3d steel.	8 in. per min.	4 h.p.
4th steel, 7 ft. long	7 in. per min.	4 h.p.

Speaking of the other makes of electric drills Mr. Barnes says: "In my opinion there is as yet no electric drill able to compete with the small air drills. The Box is probably the most practical now on the market for light mining, and, when given reasonably careful handling, will do good work. The personal factor enters more into the operation of electric drills than anywhere else, the careful operator being the chief necessity for successful work; unfortunately, however, he is extremely hard to find."

This, we believe, sums up in a few words the electric drill situation, as, with one exception, these drills require the most careful handling in order that good results may be obtained, and anyone who has seen the treatment that the ordinary drill runner gives his drill, will be inclined to believe that the electric drill is up against an extremely difficult proposition.

INTERCOOLERS FOR AIR COMPRESSORS.

The general subject of air compressor design has received very little attention at the hands of the technical press and there is probably less reliable data available upon the subject than on the design of almost any other class of machinery. COMPRESSED AIR has always endeavored to keep its readers informed of the latest information to be had on this important subject and from time to time has published articles of importance bearing directly on air compressor design. In July, 1901, (Vol. VI, No. 5) we published a comprehensive article on the subject of valves and valve areas for air cylinders, and later have published many other articles containing information and data of value to designers and builders of air compressors. As a general rule, it might be said that the men who are in a position to write authoritatively upon the subject keep their knowledge to themselves and seldom publish facts and figures which would be of value to the designer. It is therefore of more than passing interest to note an article by Mr. H. V. Haight in a recent issue of *American Machinist*, treating of the proper design of intercoolers for air compressors. Mr. Haight was confronted with the problem of designing two air compressors of 4,000 cu. ft. of free air per minute capacity in connection with which it was guaranteed that the temperature of the air passing from the low pressure to the high pressure cylinders should be reduced to within 15 degrees of the temperature of the cooling water supplied to the inter-

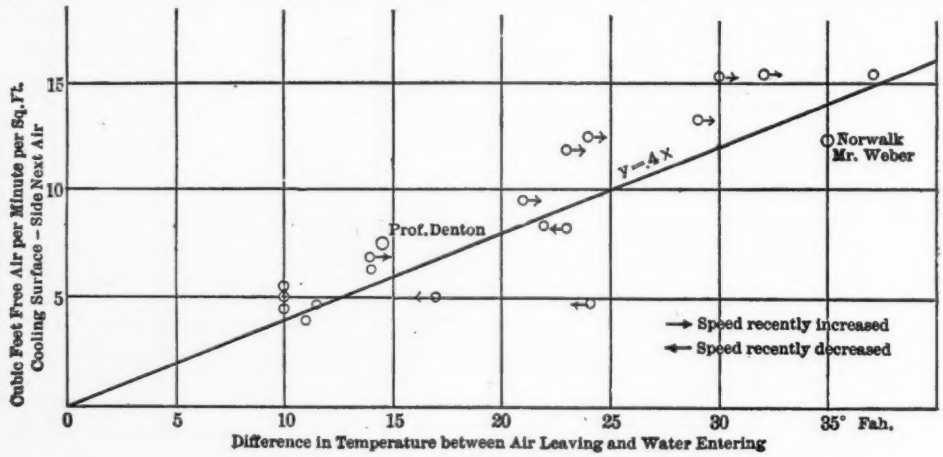


FIG. I. PLOTTED RESULTS OF THE TESTS.

cooler. In each case there was a penalty of $150 per degree for every degree more than 15, and a bonus of $150 for every degree less than 15.

In order that some exact information might be had on the subject, a thorough test was made of a Rand two-stage machine by Mr. F. C. Weber, the results of which we reproduce in Figures 1 and 2. In this test the compressor was run but a short period at each speed, not long enough for the temperatures to come to their final values, and two sets or readings were taken, one as the speed was being increased step by step and one as it was being decreased step by step. These results were plotted, as shown in Figure 1. (Figure 2 shows

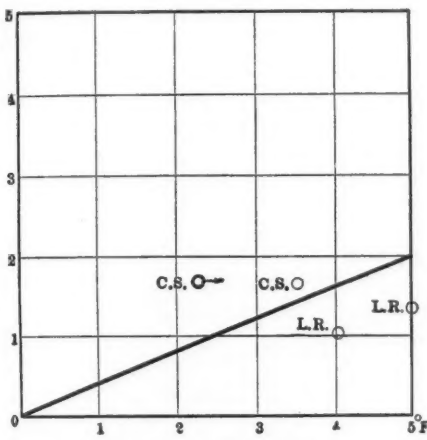


FIG. 2. TEST OF A LARGE COMPRESSOR WITH LARGE INTERCOOLER.

the corner square of Figure 1 drawn to a larger scale.)

Mr. Haight draws a number of interesting conclusions from these diagrams, among which might be mentioned the fact that to reduce the temperature of the air to within 10 degrees of the temperature of the water requires an intercooler twice as large as one to reduce the temperature to 20 degrees above the temperature of the water, while an intercooler to reduce the temperature to 1 degree above temperature of the water would require to be 10 times as large as one to reduce the temperature of the air to 10 degrees above that of the cooling water. The quantity of heat transmitted through a given area of the tube surface varies as the square of the difference in temperature.

Another interesting point brought out by the experiments is that copper tubes are less efficient than iron tubes, presumably because copper tubes are very smooth, while iron tubes are somewhat rough, which practically increases the real area of the surface, somewhat on the principle of a pin radiator or an air-cooled automobile engine cylinder.

It is gratifying to note that from the information acquired in making the above tests, Mr. Haight was enabled to design an intercooler which reduced the temperature of the air to within 5 degrees of that of the water and so earned a bonus of $1,500 for his company.

WORKING UNDER HIGH AIR PRESSURES

Matthew Vingol. in a recent issue of the *Engineering and Mining Journal*, writes that on account of the extended tunneling operations beneath the Seine, for the various lines of the Paris Metropolitan railway, the Prefect of the Seine thought well to obtain the opinion of a committee appointed to consider the hygienic conditions of the workers in compressed-air workings, and to this end a commission, composed of Drs. Armand Gautier, Roux, Haller and Walckemar were appointed early in the year. The report of this committee has been presented to the Academy of Medicine and contains the following conclusions, which should be of interest to engineers engaged in tunneling operations:

1. That so long as work in the compressed air is done, as at present, under pressures less than 2 kg. per square centimeter above the surrounding air pressure the duration of work may be the same for the workmen as in work in the open air.

2. It would be an advantage from the point of view of the health of the tunnel workers that they be submitted but once during 24 hours to the change of pressure necessitated by work in the caissons. The duration of work should be a maximum of 10 hours consecutively, including time of entering and leaving the caissons.

3. In case it is necessary that the workmen start work twice within 24 hours a complete repose of eight hours at least is necessary between such starts. In any case overwork and accidents can only be avoided by the observance of the rules indicated below.

4. Medical inspections, periodical and frequent, are essential to verify the physical aptitude of the workers for work in compressed air, as much for new workmen as for the experience workers engaged.

5. The duration of the period of entrance and exit from the workings by stages should not be less than five minutes per kilogram pressure.

6. The exit from the pressure should always be long and progressive and such dispositions should be taken that the pressure should not be equilibrated in less than four minutes. An experienced and responsible man should be appointed to oversee the duties connected with the equilibrating of the pressure.

7. In each caisson a medical post should be established for immediate needs.

In view of the importance of these recommendations, which are subscribed to by the best medical men in Paris, it is highly probable that they will be accepted in their entirety for the compressed-air workings beneath the Seine.

TRADE PUBLICATIONS

The Chicago Pneumatic Tool Company, Fisher building, Chicago, announce the fact that they will receive from the printers their new compressor catalog, consisting of 118 printed pages, printed in two colors, in which several new types and sizes of compressors are shown, including their new Hamilton Corliss machines. Those interested will receive a copy on request. This company has also issued Catalog No. 19, devoted to Keller stone carving tools and plug drills. This catalog is handsomely illustrated, printed on heavy paper, 6x9, 50 pages.

Western Wheel Scraper Company, Aurora, Ill. New edition of their catalogue devoted to wheel scrapers, drag scrapers, Western reversible steel road machine, rock crushers, flat cars, dump cars, etc. One hundred pages, 7x10.

Willis Shaw, Chicago, Ill. Six page booklet devoted to a description of Quincy hoists, with table of horsepowers, sizes, net prices, etc.

Stanley-G. I. Electric Manufacturing Company. Bulletin 609, superceding bulletins 25 and 194, devoted to G.-I. floor and wall outlet boxes. Circular 786 devoted to the new type K arc lamps. Circular 787 devoted to direct current motors and generators. All Stanley-G. I. literature is obtainable by addressing the company at Pittsfield, Mass.

The Philadelphia Lubricator and Manufacturing Co., Inc. 1525, Land Title building, Philadelphia, Pa. Twelve page booklet devoted to a description of the Philadelphia grease cup.

C. T. Carnahan Mfg. Co., 36th and Wazee streets, Denver, Colo. Forty page booklet, 7½x5, devoted to the Murphy air hammer rock drill. Fully illustrated and containing notes on steel, automatic feeders, standards, cleaners, sharpening tools, etc.

Traylor Engineering Company, 114 Liberty street, New York. Handsome 56 page catalog, 6¾x9, devoted to stamp milling machinery, stamp mills, mortars, ore feeders, rock and ore crushers, amalgamating pans, settlers, agitators, retorts, etc.

Hardsocg Wonder Drill Company, Ottumwa, Iowa. Devoted to a description of the Little Wonder Side Valve Drill, the Little Wonder trigger valve drill, Wonder air feed drill, Great Wonder mounted drill and the Wonder air feed mounted drill. Twenty-four pages, 6x9.

The Automatic Refrigerating Co., Hartford, Conn. Twelve page booklet, illustrating and describing their automatic ammonia refrigerating plants.

Baldwin Locomotive Works, Philadelphia, Pa. Record No. 58, being a handsomely printed book illustrating and describing the ceremonies coincident to the unveiling of the statute of Mathias W. Baldwin in front of the main office building of the company.

Wier and Craig Mfg. Co., 2421 Wallace street, Chicago, Ill. Eight page booklet describing the Pilling Air Engine for turntable devices, transfer tables, portable and stationary hoists.

Western Tube Company, Kewanee, Ill. Booklet treating of a new discovery in bronze mixture known as "High Duty Metal." This metal, when subjected to high temperatures, shows a loss in efficiency of only 5.6%, while ordinary mixtures show a loss of efficiency of from 400 to 500% when subjected to the same conditions. This metal, therefore, marks a great advance over other mixtures for the use of high-speed tools.

A. & Z. Daw, 11 Queen Victoria St., London, E. C., England. Catalog 7x9½ devoted to compressed air, its production and use. This catalog contains a very thorough description of the "Daw" Patent Compressor for air and gas. It also treats of blowing engines, air washers, intercoolers, aftercoolers, air reheat-

ers, and auxiliary plants. The catalog is well worth having as it contains many valuable curves and tables covering the theory and practice of compressed air.

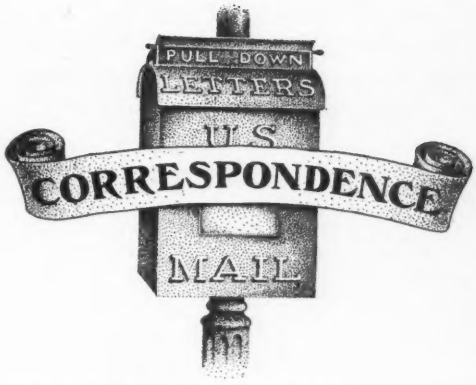
Association of Licensed Automobile Manufacturers, 7 E. 42nd St., New York. Bulletin No. 18, 8½x11, setting forth this association's standard for Hexagon head screws, castle and plate nuts with many diagrams, tables and detailed specifications.

Ingersoll-Rand Company, 11 B'way, New York. Catalog No. 452B, 6x9, devoted to a description of the latest models of Ingersoll-Sergeant Rock Drills. It gives tabulated specifications of each type and size, with comments on the work for which each is adapted. A list of 44 questions covering the problems of rock drilling under all conditions is included in the book. The catalog closes with several pages devoted to tables of useful information on compressed air.

Curtis & Co. Manufacturing Company, St. Louis, Mo. Eight-page booklet 3½x6½, illustrating and describing single and double eye beam traveling cranes, light bridge cranes, low head room traveling cranes, and pneumatic hoists.

Pullman Manufacturing Company, Rochester, N. Y. Catalog 6x9, 102 pages, describing the numerous hardware specialties manufactured by this company. The catalog is profusely illustrated and contains many tables, specifications and prices.

A Hungarian physician has invented an apparatus which, producing alternate compressions of air and vacuums, causes patients who are apparently dead to breathe with all the natural motions of a live person. In the case of persons who are taken unconscious from the water or suffering from asphyxiation as a result of inhaling deadly gases, or who have ceased breathing from electric shock—in all these cases life is frequently saved after one to four hours of artificial respiration. Many deaths occur not because means of artificial respiration are not resorted to, but because people do not use proper means. To work the arms properly requires practice. This new device will do away with all this and if put in general use we may expect a lessening in the number of summer tragedies.



To the Editor of Compressed Air:

DEAR SIR:—I am in receipt of a circular from the Samson Leather Tire Co., 12 West 23rd St., New York, in which occurs the following paragraph:

"The pressure of the air inside a tube heated from 68° to 194° makes an increase of only one-eighth, viz: a tire inflated with 85 lbs. per square inch, on an ordinary temperature, will increase to 95.63 lbs. should the tire become heated as much as is possible for it to be. But this pressure will not harm the tire, which fact has been proven by our recent experiment in inflating a 920x120 (36x4½) Samson Racing Model as much as possible, which experiment has given the following result:

"The tire reached a pressure of 426 lbs. per square inch and at that point the bead became loose from the rim, but the tire did not explode."

In reading this paragraph it struck me that the figures of the Samson Company were not altogether accurate, and I accordingly made a few calculations on the subject myself which tended to confirm me in my opinion. I would greatly appreciate it, however, if you would inform me of the correct solution. I realize, of course, that the matter is of very little importance and simply desire the information as a matter of interest.

J. S. COOKSON.

The absolute pressure of air varies directly as the absolute temperature when the volume remains constant. The absolute pressure in this case is $85 + 15 = 100$ lbs. per square inch.

The absolute temperatures are:

$$68 + 461 = 529$$
$$\text{and } 194 + 461 = 655$$
$$\text{then } 529 : 655 :: 100 : x$$

From which $x = 123.81$ lbs. per square inch absolute, or 108.81 lbs. gauge, instead of 95.63 as given in the Samson circular. It is evident, therefore, that this company made an error in its calculation.

INDUSTRIAL.

THE COST OF LEAKAGE IN COMPRESSED AIR PLANTS.

Few people realize that leakage plays an important part in the efficient operation of a compressed air plant. Many concerns will go to great expense in installing high class air compressors with compound steam cylinders and two stage air cylinders, but when it comes to installing the pipe line the utmost carelessness is displayed, the same fittings being used that would apply to a steam line without the fact being taken into consideration that steam and air are two very different mediums. The heat of the steam tends, of its own accord, to keep joints tight which, if cold, would leak considerably. One has only to go into an ammonia refrigerating plant to be convinced of this fact. In such a plant special ammonia fittings are generally installed to guard against leakage in cold pipe joints. These fittings comprise a pair of flanges with a rubber sleeve held between them which is compressed when the flanges are drawn together. One would naturally believe that such a connection would be absolutely tight, but this is not always the case as there are very few ammonia plants in which the odor of ammonia is absent. How much more must this leakage be in a compressed air plant where ordinary pipe fittings are in use and where the escape of air is not noticeable to the senses and so is less likely to be detected.

In order that an estimate may be made of the cost of compressed air leakage, the following figures have been compiled to cover the compressed air plants in ordinary use, i. e., the large central power plant, the medium plant for mines and quarries, and the small plant for manufacturing establishments.

THE CENTRAL COMPRESSED AIR POWER PLANT.

This plant, while often very much larger, we will consider to have a capacity of 10.000 cu. ft. of free air per minute and assume that there is leakage of 1 per cent., or 100 cu. ft., of free air per minute. The horse power required to compress 100 cu. ft. to 100 lbs. in a two-stage compressor would be 17.6 (allowing 15 per cent. for friction in the machine). Considering the cost of this power to be 2 cents per horsepower per hour, the cost of the leakage will be 25.2 cents per hour, or $3.52 per ten hour day, amounting to $1,056 at the end of the year of 300 working days. Even if the leakage only amounted to one-half of 1 per cent., the loss would come to over $500 per year.

THE MEDIUM PLANT.

We may assume that this plant has a capacity of 1000 cu. ft. of free air per minute. If we consider the leakage to be 1 per cent., as in the first case, the loss would amount to 35 cents per day, or $105 per annum.

THE COMPRESSED AIR PLANT FOR MANUFACTURING ESTABLISHMENTS.

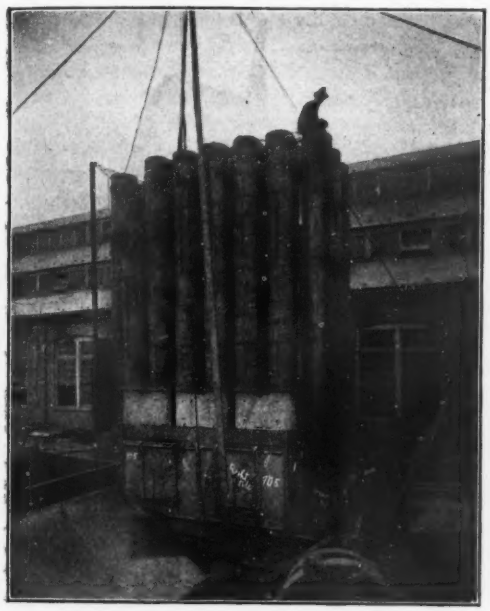
This plant is most frequently of a capacity of about 500 cu. ft. of free air per minute, but the percentage of leakage should be figured a little higher than in the previous plants, owing to the fact that more pains are taken with the larger and more expensive plants in the installation of mechinery and piping than is the case with smaller and cheaper plants. Furthermore, most manufacturing establishments require a more complicated distribution of the compressed air and the installation of more valves, bends and outlets is needed. It is therefore more fair to consider the leakage as being 2 per cent. in these cases. The compressor will very likely be a single stage one and the horsepower required to compress the leakage of 10 cu. ft. per minute to 100 lbs. pressure will be $.207 \times 10 = 2.07$. At 2 cents per horsepower per hour this leakage would cost 41.4 cents per ten hour day, or $124.20 per year.

It will thus be seen that in every plant the problem of leakage is an important one. But leakage is not the only item of expense in connection with a compressed air installation; there is also the cost of maintaining the pipe lines in good condition, replacing gaskets, tightening up joints, etc. This usually amounts to a considerable expense and should be taken into consideration by compressed air users. It is to counteract these losses that the Goldschmidt Thermit Company, 43 Exchange place, New York City, are introducing their Thermit Process for welding the joints in compressed and refrigerating pipe lines and thus produce a continuous line of pipe in which leakage would be entirely impossible and the cost of maintenance eliminated.

THE GIROUX HOT BLAST TOP.

Among the recent shipments made to Mexico from the works of the Traylor Engineering Co., at Allentown, Pa., was a 42" x 160"

copper smelting furnace for the National Metallurgical Co., of Matehaula. This furnace was to be fitted with a Giroux Hot Blast Top. This Top has since been completed and shipped. Illustrations of the top showing it complete, and also in process of erection, showing the internal construction, are given herewith. These are made from photographs at the Allentown works, where the Traylor



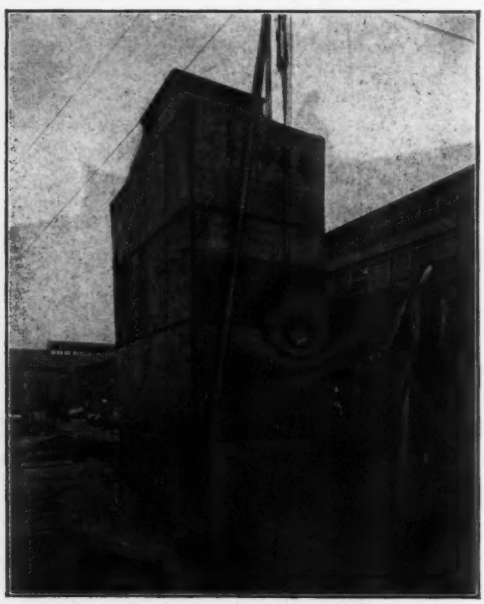
Engineering Co. assembles and erects all of its machinery complete before shipment. The Giroux Hot Air Blast Top is without doubt one of the most important money saving inventions for the smelting furnace owner that has been put on the market in many years. It was developed by a practical man who knew what he wanted to accomplish, and who knew also the mechanical faults which it was necessary to avoid. Mr. Jos. L. Giroux made the invention when he was manager of the United Verde Smelter, at Jerome, Arizona. The value of utilizing the waste heat from the furnace by using it to heat the air for the blast had been fully recognized before Mr. Giroux undertook the design of his hot blast top. The value of a hot blast for increasing the efficiency of the blast furnace was also recognized, and in addition several forms of hot blast stoves of several types had been devised. The difficulty with all the previously devised forms of hot blast tops lay in the strains produced upon them by the great expansion and contraction of their parts due to the changes of temperature. This rapidly destroyed them and the cost of keeping them in repair was fully equal to any saving due to their use.

The hot blast tops first built for the United Verde Smelter have been in constant use for the last three years. They have cost practically nothing for repairs in all of that time. Since the Traylor Engineering Co. came into control of this important device its experience with the device has been equally satisfactory. Senator Clark is now having all of his furnaces at Butte, Montana, equipped with the Hot Blast Top. A year ago the Traylor Engineering Co. completed a Top of this kind for the Giroux Consolidated Mines Co., at Ely, Nevada, and this has been in constant use ever since without requiring any attention whatever. At the present time the Traylor Engineering Co. has under construction at the Allentown works the largest copper smelting furnace ever built, and this will have a Giroux Hot Blast Top. This furnace measures 46″ x 255″, or about 21 feet in length inside the tuyeres. It was designed by the Traylor Engineering Co., of Boundary Falls, B. C.

The Giroux Hot Blast Top is applied to the furnace immediately above the feed floor. The hot gases rising from the mass of smelting ore impinge upon the sets of pipes which form the working part of the Top and impart their heat to the air within which is fed at once to the tuyeres. The blast is heated to a temperature of 400 or 500 deg. The heat thus saved is just like finding so much fuel. It reduces the fuel charge on some ones so as to make a saving of about 30% in the fuel charge. This, however, is not all the good it accomplishes. It increases the capacity of the furnace from 15% to 25%, and also allows of the use of charges of ore carrying from 2% to 4% more silica. The hot blast gives a more uniform smelting temperature and seems to prevent to a large extent the crusting or building up on the walls of the furnace, such as is customary in general practice.

The Giroux Hot Blast Top consists mechanically of two series of metal pipes arranged symmetrically around the inside of the top of the furnace, the lower ends of one set of the pipes being just above the top of the charging door. The vertical portion of the pipes is built of sheet steel. These are circular at the bottom where they join the return elbows,

and oval and of larger section at the top. The material of the pipes makes them readily permeable to the heat, and their form gives them a large surface for absorbing the heat from the furnace gases. Their form also prevents dust from adhering to them and reducing their capacity for absorbing heat. Near their tops the pipes are connected together sidewise in pairs by means of flanged cast iron connections, and at the bottoms each pair of pipes is connected by means of cast iron return elbows to form a continuous series on each side of the furnace. These elbows have a V-shaped



section with one side of the V lying parallel with the side of the furnace top, and the other forming a slope for the hot furnace gases to impinge against.

The Adams-Bagnall Electric Co. announce that Mr. R. C. Campbell has been placed in charge of their Philadelphia office as special agent. Mr. Campbell is an engineer of experience and, until recently, was employed by the Curtis Steam Turbine Co., where he had charge of the tests which resulted in the design of Mr. Curtis's new marine turbine. Mr. Campbell will make his headquarters at 905 Arch street, Philadelphia, where communications addressed to him will have prompt attention.

CHIPPINGS.

IN the cylinders of a compressed-air locomotive, only a low cold-test oil should be used. The oil should show a specific gravity of about 29, and a cold test of —5° Farhenheit.

Where compressed air is carried through pipes into the mine, it should be remembered that in case of fire these pipes can be utilized to carry water into the mine. Also in case of an explosion it is sometimes possible for the men to secure air through the pipes.

Compressed air for pumping is applied in the air-lift more commonly than in any other form of apparatus. The reasons for the popularity of the air-lift are the absence of working parts in the well, low maintenance charges, assured maximum yield from any well, and the possibility of pumping a number of scattered wells from a central compressing plant.

Powder should never be taken into mines in cars propelled by electricity. In case of a wreck, the live wires are liable to come in contact with and set off the powder. In all cases the utmost care must be experienced in carrying powder to the faces.

Another argument for compressed air. The compressed air locomotive is absolutely safe.

The use of compressed air to force water or fluids along a horizontal line has generally been considered inefficient. Wherever a horizontal run must be made, it is preferable to either (1) pump the water high enough in the first place so that it may make the horizontal run by gravity or (2) raise the water by air-lift to a reservoir or tank and pump it thence by means of a pneumatic displacement pump to the desired point.

As a lubricant for air compressors, graphite has a number of attractive qualities. It is generally conceded that ignitions and explosions in compressors are due to the character and quality of the lubricant used. The best oils are likely to give off vapors and must be used sparingly. Soapsuds are also used, but must be applied in large quantities and are apt to rust the machinery when not in use. Graphite is without these deleterious qualities. It is inert, unaffected by high temperatures, and can not vaporize, ignite or cause explosion.

THE difference of cost for installation of a compressed air cleaning system in a 50 x 125 foot building of three floors, as against a building with a frontage of 150 feet with four floors and basement, is very slight, the difference only requiring extra piping. Where a store is much larger than this, a more powerful dynamo or engine would be required.

The machinery is situated in the basement. It is then necessary to pipe the building so that the openings would be sufficiently numerous on each floor for a 50-foot hose to cover the entire floor space.

The cost of equipping a store of, say 100x 125 feet, with a mechanical cleaning plant operated by means of compressed air and vacuum, would be somewhere between $700 and $1,000, but for what is known as the vacuum system only the figures would be double, if not more. Both plants require about a 7½ h. p. motor, and if the building is ten stories, a 10-h. p. motor will be necessary.

An entirely new system of street cleaning likely will be abopted by the city of Pittsburgh. Officials of the department of public works are experimenting with a modern apparatus, which may take the place of the old street sweepers and a number of "whitewings."

The downtown streets are being cleaned after each midnight with flushing machines. They have been successfully tried in Washington, St. Louis and other cities. The idea is to give them a thorough test, and if they are successful a number of the machines will be purchased.

The machine, which is simple in construction, consists of a water tank, from which the water runs, sending a spray downward that covers a space equal to one-half of a street. The water falls in such a form that it starts a current toward the gutter.

The force of the stream is gained from a tank filled with compressed air located at the front end of the vehicle. The air is sent into the tank by the force of the water as it is taken from the ordinary street hydrant.

The objection to the old-fashioned sweeper is that it never carries away all of the filth that accumulates on a street, but when the surface is wet the brooms have a tendency to pack down the mud instead of carrying it away. Should the street be cleaned with the old-fashioned sweeper before the surface has been dampened, it crates a dust that is almost unbearable.

Another advantage the flushing machines have over the old method of cleaning thoroughfares, is that it will be unnecessary for a corps of men at stated periods to wash the streets by the use of hose. It is expected that should the city adopt the flushing machines it will save thousands of dollars each year.

Three machines are now being tried. Three more from a different corporation are now on the way to Pittsburgh, and both will be given a thorough test before either is adopted. The machines cost about $1,000 apiece, but their maintenance does not cost anything. On an ordinary street sweeper it is necessary to equip them with new brooms at least once a week, which amounts to considerable at the end of the year.

WOOD PRESERVED BY HEAT.

Method Which Has Just Been Patented in France.

One of the latest methods of preserving wood has been patented in France. It has been recognized that one of the best means of preservation is to keep the wood at a high temperature in closed vessels (about 250 degrees C.) and at the same time at a high pressure, some 250 pounds per square inch. This method has been perfected by the inventor. The object of the improvements is to provide means of heating as efficacious as usual, but more practical and economical. Another aim is to utilize a part of the air pressure which has served in compressing. In the new process the pieces of wood are put in compression cylinders and the air is sent direct from the compressors into the cylinders. To heat the air each cylinder is surrounded by a masonry envelope not in contact with it, thus leaving a free space. The hot gases from a furnace are circulated in this. Cooling is effected by introducing cold air in the space. To obtain a specially good and cheap heating a series of gas jets is placed in the lower part of the air jacket and fed by a gas tube and having an air tube to aid in combustion. When the plant uses several cylinders side by side there is a saving in the work of air compression by utilizing a part of the compressed air in a cylinder at the end of the operation to send it into the next cylinder in commencing the compression here. Piping is arranged between the cylinders for this purpose.

827,518. LUBRICATOR FOR PNEUMATIC MACHINERY. EDWIN A. EMERY, Cripple Creek, Colo., assignor to The Emery Pneumatic Lubricator Company. Filed May 28, 1902. Renewed May 19, 1906. Serial No. 317,794.

827,536. AIR-CLEANING APPARATUS. GEORGE J. KINDEL, Denver, Colo. Filed Sept. 26, 1905. Serial No. 280,121.

827,690. PNEUMATIC MALTING-DRUM. FRANKLIN B. GIESLER, Milwaukee, Wis. Original application filed Feb. 10, 1902. Serial No. 93,297. Divided and this application filed Nov. 15, 1905. Serial No. 287,428.

827,705. PNEUMATIC HORSE-COLLAR. JOHN R. BURKHOLDER, Lancaster, Pa. Filed March 16, 1906. Serial No. 306,420.

827,714. AIR-PUMP. NAPOLEON W. DIBLE, Kansas City, Mo. Filed Oct. 4, 1904. Serial No. 227,103.

827,750. BLOWING MACHINERY. AUGUSTE C. E. RATEAU, Paris, France, assignor to Rateau Turbine Company, Chicago, Ill., a Corporation of West Virginia. Filed Dec. 24, 1902. Serial No. 136,455.

827,839. AIR-BRAKE AND MEANS TO START AUTOMOBILES. Geo. W. Young, Glendale, Cal. Filed Jan. 23, 1906. Serial No. 297,456.

827,891. MEANS FOR INCREASING THE WORK OBTAINABLE FROM A CHARGE OF COMPRESSED AIR. WILLIAM H. SODEAU, Newcastle-upon-Tyne, England, assignor to Sir W. G. Armstrong, Whitworth and Company, Limited, Newcastle-upon-Tyne, England. Filed May 9, 1905. Serial No. 259,580.

Claim. The combination with apparatus for heating a body of compressed air of the type in which liquid fuel is fed into the compressed air by the expansion of a second body of compressed air, of means for allowing part of the second body of compressed air to escape before the whole of the fuel has been delivered.

827,926. MEANS FOR INFLATING RUBBER TIRES. ALFONSO G. LAVERTINE and JAMES E. MCNELLAN, Johannesburg, Transvaal. Filed Oct. 10, 1905. Serial No. 282,109.

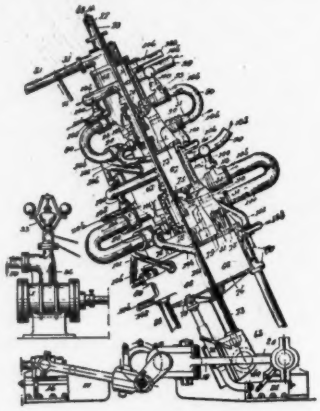
827,927. PNEUMATIC TIRE. HENRY D. B. LEFFERTS, Orange, N. J. Filed Nov. 17, 1905. Serial No. 287,805.

828,254. TIRE. JAMES H. SWAIN, Pittsburg, Pa., assignor, by mesne assignments, to H. M. & S. Armored Tire Company Incorporated, Pittsburg, Pa., a Corporation of Pennsylvania. Filed Aug. 14, 1905. Serial No. 274,123.

828,270. APPARATUS FOR MAINTAINING AIR-PRESSURE IN ALE AND BEER CASKS. EDWARD R. BROWN, Boston, Mass., assignor, by mesne assignments, to Wilber F. Lakin, trustee, Quincy, Mass. Filed June 4, 1901. Serial No. 63,058.

828,295. COMPRESSED-AIR MOTOR. IVAN W. AMMON, St. Petersburg, Russia. Filed Sept. 24, 1903. Serial No. 174,411.

Claim. The combination in a motor operated by compressed and heated air of three cylinders in which the compressed and heated air expands successively, of a crank-shaft, driven through connecting-rods by the piston-rods of the driving-pistons, two air-compressors, operated by means of connecting-rods by the said main shaft, the axial line of each of these compressors making a suitable angle with the working axial line of the cross-head operating the pistons of the corresponding compressor by means of a connecting-rod, the length of this connecting-rod, the stroke of the compressor-piston and that of the cross-head being equal, as described and shown.



828,432. MEANS FOR INCREASING THE WORK OBTAINABLE FROM A CHARGE OF COMPRESSED AIR. WILLIAM H. SODEAU, Newcastle-upon-Tyne, England, assignor to Sir W. G. Armstrong, Whitworth and Company, Limited, Newcastle-upon-Tyne, England. Filed May 9, 1905. Serial No. 259,581.

Claim. The combination of a reservoir for compressed air, a reservoir for fuel, a pipe having one end in the air-reservoir and the other end standing up in the lower part of the fuel-reservoir, the latter end being perforated with two or more holes at different heights, and means for igniting and burning the fuel in the air-reservoir.

828,498. AIR-FEEDING DEVICE FOR STEAM-GENERATORS. CHARLES D. MOSHER, New York, N. Y. Filed July 17, 1903. Serial No. 166,055.

828,522. AIR-COMPRESSOR. THEODORE H. SMITH, San Francisco, Cal. Filed May 27, 1905. Serial No. 262,623.

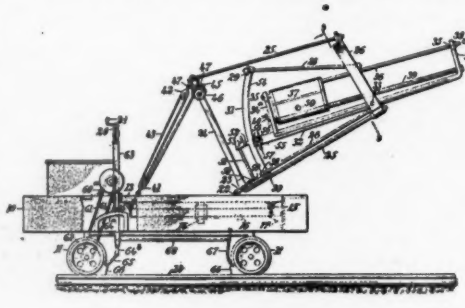
828,590. APPARATUS FOR INTRODUCING POWDERED ELEMENTS INTO CASTINGS. FRANK G. WRIGHT, Indiana Harbor, Ind., assignor to American Steel Foundries, Chicago, Ill., a Corporation of New Jersey. Filed Feb. 23, 1906. Serial No. 302,420.

828,592. CENTRIFUGAL FAN. WILLIAM E. ALLINGTON, Saginaw, Mich. Filed Jan. 30, 1905. Serial No. 243,204.

828,635. AIR-BRAKE SYSTEM. NEWTON R. BEAUCHAMP, Atlanta, Ga. Filed April 20, 1906. Serial No. 312,872.

828,641. TIRE FOR MOTOR-CARS. ISIDORE CLIFFORD, London, England. Filed Aug. 4, 1905. Serial No. 272,748.

828,684. ROCK-DRILL. JOHN E. SALES, Wrangell, Alaska. Filed May 10, 1905. Serial No. 259,740.



Claim. In a rock-drill, a car, a turn-table on the car, a main frame pivoted to the turn-table, means for adjusting said frame, a secondary frame pivoted in the main frame to swing in a plane at right angles to the plane of movement of the said frame, means for adjusting the secondary frame, a supporting-bar pivoted in the secondary frame to swing in a plane at right angles to the plane of movement of the secondary frame, said bar carrying guide-rods, means for adjusting the supporting-bar, a motor mounted to slide on the guide-rods of the supporting-bar, and means for sliding the motor on said bars.

828,781. PNEUMATIC CUSHIONED STOOL. CHESTER SMITH, Oak Hill, Ohio, assignor of one-half to David E. Evans, Oak Hill, Ohio. Filed March 9, 1906. Serial No. 305,167.

828,827. ELASTIC-FLUID TURBINE. JAMES C. PRESCOTT and HENRY A. PRESCOTT, Philadelphia, Pa. Filed Sept. 25, 1905. Serial No. 280,015.

828,861. SHAFTING FOR CAISSONS AND THE LIKE. DANIEL E. MORAN, Mendham, N. J., and JOHN W. DOTY, New York, N. Y. Filed April 4, 1906. Serial No. 309,850.

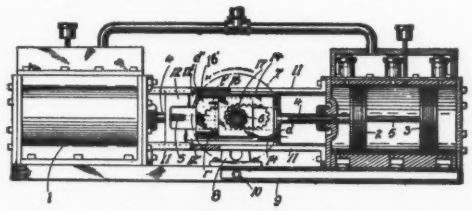
828,939. AIR-PRESSURE BRAKE. ERWIN KRAMER, Berlin, Germany. Filed Aug. 3, 1904. Serial No. 219,402.

829,143. AIR-BRAKE SYSTEM. FRED B. COREY, Schenectady, N. Y., assignor to General Electric Company, a Corporation of New York. Filed Dec. 29, 1905. Serial No. 293,753.

829,712. PLASTIC-MOULDING MACHINE. WILLIAM S. GODWIN, New York, and CHARLES I. WILLIAMS, Utica, N. Y. Filed Feb. 2, 1905. Serial No. 243,792.

829,707. MACHINE FOR TREATING AIR. JOHN W. FRIES, Winston Salem, N. C. Filed Sept. 28, 1905. Serial No. 280,437.

829,441. AIR PUMP OR COMPRESSOR. CHARLES O. SOBINSKI, St. Louis, Mo. Filed Dec. 19, 1904. Serial No. 237,538.



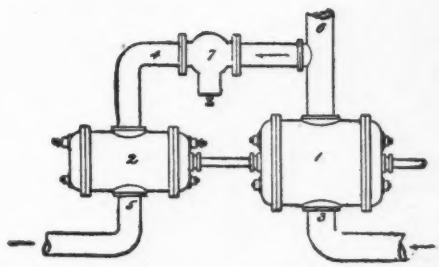
Claim.—1. In a pump, a pair of juxtaposed cross-heads simultaneously reciprocating in opposite directions formed on their adjacent faces, interiorly-toothed plates confined in said depressions and susceptible only of a movement therein at right angles to the axis of reciprocation of the cross-heads, a tongue and grooves and a rib between the grooves formed on each plate, the tongue oof one plate operating in the groove on either side of the rib on the opposite plate, a drive-shaft, and a pinion on the shaft engaging the toothed surfaces of the openings of the plates, the parts operating substantially as, and for the purpose set forth.

830,433. PNEUMATIC DISCHARGING DEVICE FOR LIQUIDS. ISAAC W. HEYSINGER, Philadelphia, Pa. Filed Aug. 21, 1905. Serial No. 275,066.

829,941. PNEUMATIC FOR MUSICAL INSTRUMENTS. JACOB BINNING, Boston, Mass., assignor of one-half to Mason & Hamlin Company, Cambridge, Mass., a Corporation of Delaware. Filed July 10, 1905. Serial No. 268,912.

830,503. COMPOUND AIR-COMPRESSOR. EBENEZER HILL, Norwalk, Conn. Filed Aug. 18, 1905. Serial No. 274,657.

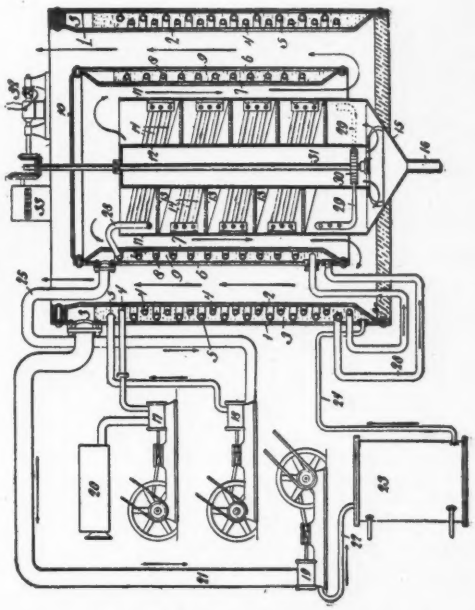
Claim.—1. The combination in a compound compressor of a low-pressure cylinder, a high-pressure cylinder, a duct connecting the discharge of the low-pressure cylinder with a choke-valve in the duct between the cylinders arranged to open and close the passage through the duct according to the pressure in the duct between said valve and the low-pressure cylinder, substantially as specified.



830,538. PNEUMATIC VANNER. ALBERT H. STEBBINS, Little Rock, Ark. Filed Aug. 19, 1904. Serial No. 221,424.

Claim.—1. In a machine of the class described, the combination of a main supporting-frame, a belt-carrying frame mounted to swing from said main frame, an inclined concentrate-belt formed of sheet metal and carried by said belt-carrying frame, said sheet-metal belt having perforations, the walls of which are disposed to direct fluid-currents over and substantially parallel to said belt, and a fluid-chamber beneath the upper run of said belt for directing fluid-currents through said perforations.

830,613. APPARATUS FOR LIQUEFYING AIR AND OTHER GASES. RAOUL P. PICTET, New York, N. Y. Filed Jan. 12, 1901. Serial No. 42,951.



Claim.—1. In an apparatus for liquefying air and other gases the combination with a series of cooling vessels adapted to contain liquid refrigerants of successively lower boiling-points, each provided with cooling- pasages, for conveying the gas to be liquefied through said cooling vessels, such passages of the said vessels being connected in series, and the vessel for containing the refrigerant of higher boiling-point having other cooling-passages connected with the vessel for containing refrigerant of lower boiling-point, and forming cooling-passages for the refrigerant of lower boiling-point, of means for compressing the vapor of the refrigerant of lower boiling-point, and for passing it through the corresponding cooling-passages of the vessel containing the refrigerant of higher boiling-point.

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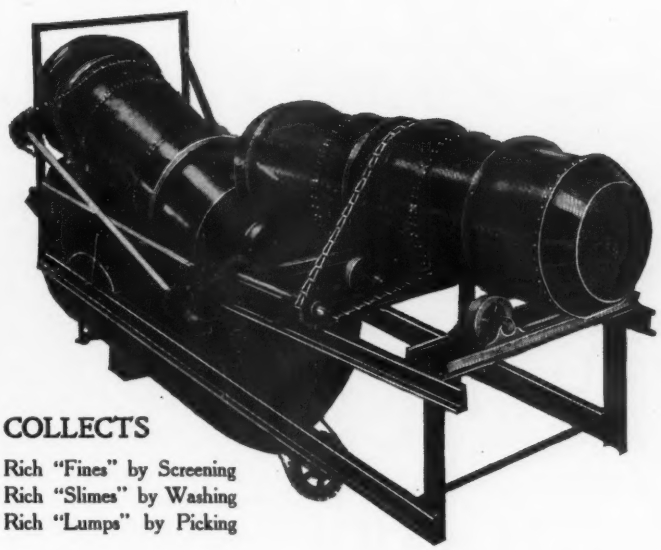

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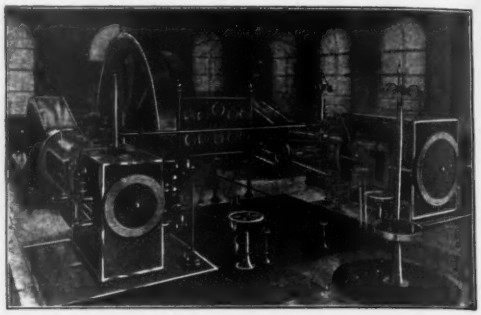

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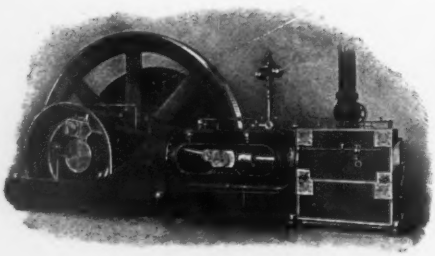

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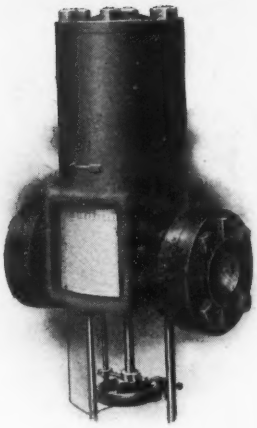

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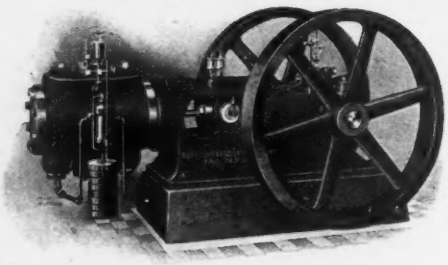

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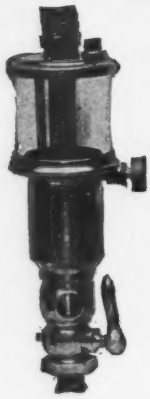

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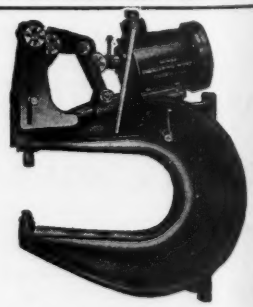

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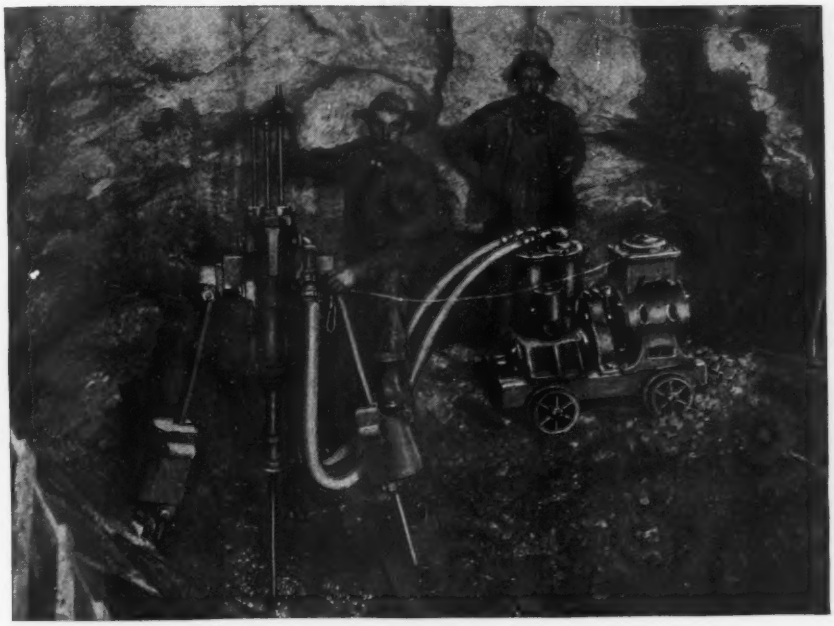

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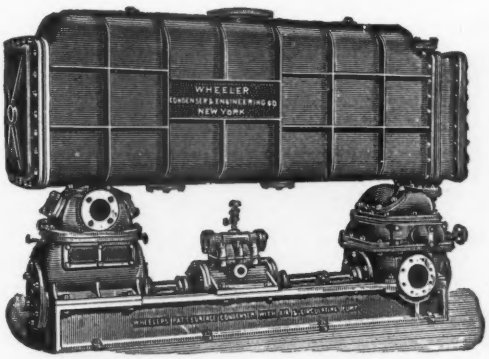

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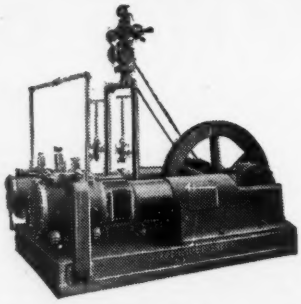

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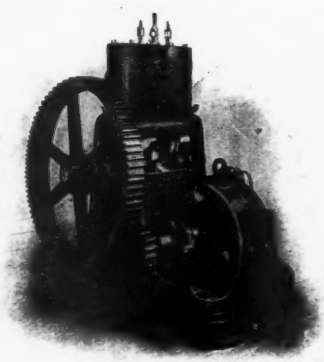

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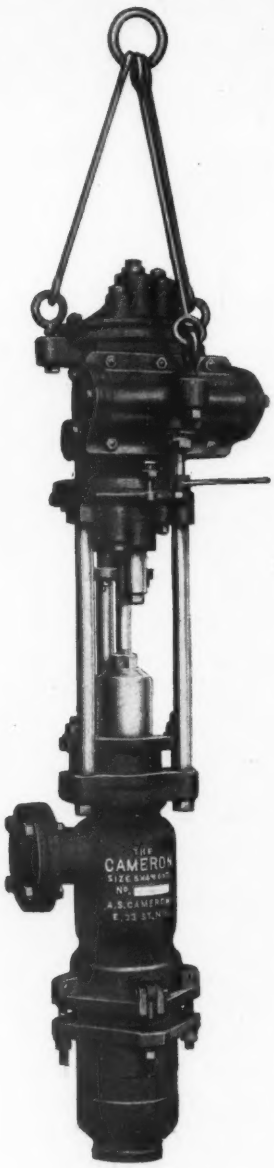

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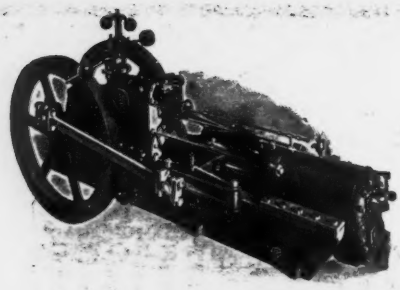

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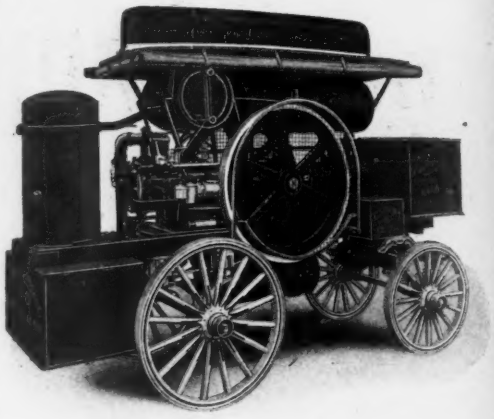

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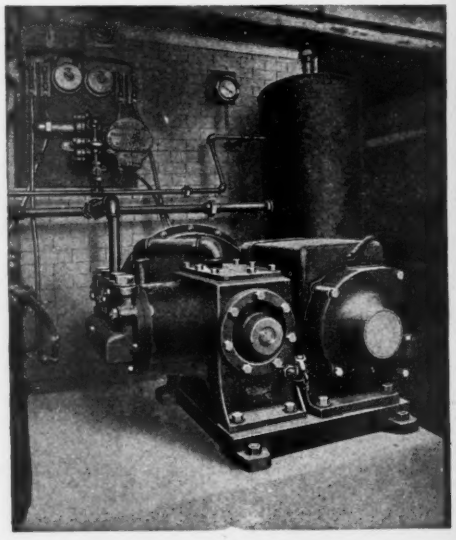

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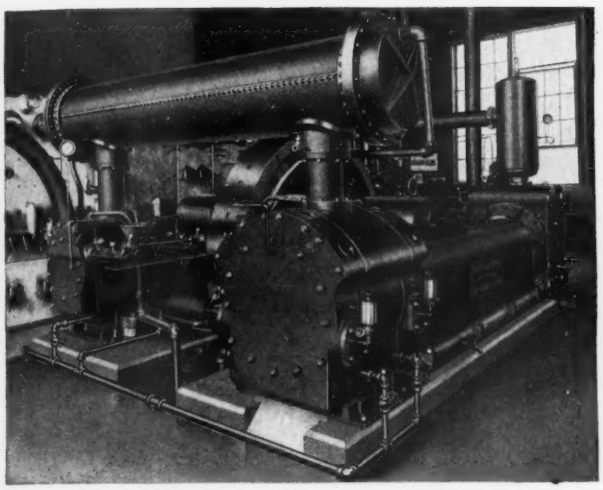

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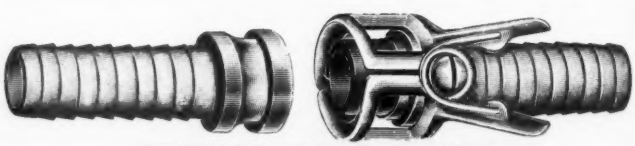

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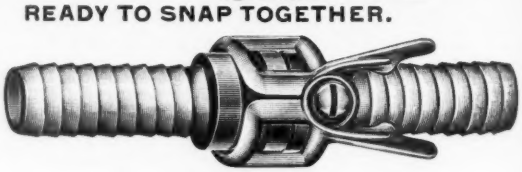

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